Can Biomass Combined Heat and Power and a District Heat Network be a viable energy service for a small town in rural Ireland?

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Abstract

This paper presents a preliminary assessment of the viability of CHP/DHN as an energy service for Stranorlar in County Donegal, Ireland. New developments in small-scale biomass CHP, along with increased application of DHN to more sparsely populated areas, suggest that this combination of RETs may be relevant to small towns in Ireland.

A questionnaire survey conducted in the area reveals a high degree of public interest in this type of energy service with 82% of the sample surveyed willing to switch to it if a 20% discount on current bills is offered. The overall heat and hot water demand of the study area, incorporating 347 houses and three anchor buildings, is calculated as 12,578,569MWh p.a.

Appraisal of a number of demand/load scenarios indicates that biomass gasification plant sized at 750kW_e or 625kW_e along with a peak-demand back-up boiler (biomass, heat-only) sized at 3MW_{th}, could meet the heating and hot water demands for the anchor buildings and 82% of households.

Investment appraisal for the 750kW_e plant, allowing for sales at 20% discount, gives a capital outlay of €9,904,349 and a payback period of 9.55 years, and is viable up to a future discount rate of 8% for a 20 year lifespan. CO_2 emissions savings are in the region of 5873kt CO_2.

A key conclusion is that Stranorlar, and possibly other small towns in Ireland, particularly where no natural gas supply exists, could benefit from this energy service and contribute to government targets both on RE and on emissions reduction. Full-scale feasibility studies are therefore recommended.

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Cover image: Flaxington,D. (2007)

List of Abbreviations and Acronyms

AD	Anaerobic Digestion
BEL	Biomass Engineering Limited
BER	Building Energy Rating (Ireland)
CHP	Combined Heat and Power
CHPA	Combined Heat and Power Association (UK)
CHPDP	Combined Heat and Power Deployment Scheme (Ireland)
DHN	District Heating Network
ESB	Electricity Supply Board (Ireland)
IEA	International Energy Agency
NCV	Net Calorific Value
ORC	Organic Rankin Cycle
RE	Renewable Energy
RET	Renewable Energy Technology
REFIT	Renewable Feed In Tariff
SEI	Sustainable Energy Ireland (to 2010)
SEAI	Sustainable Energy Authority Ireland (formerly SEI)
WDC	Western Development Commission

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Chapter 1. Introduction

1.1 Background

The urgent need to mitigate climate change through a range of energy efficiency measures and renewable energy (RE) sources is widely acknowledged and legally binding targets for European Union member states represent a commitment to implement these.

The European Commission has committed to a target of 20% RE consumption by 2020, with individual nation states having their own targets. Under EU Directive 2009/28/EC, Ireland's target is set at 16% overall, including the electricity, heat and transport[1] sectors. In 2010, electricity consumption from renewable sources stood at 14.8% and needs to increase to 40% by 2020 (DCENR 2012, SEAI 2011). It is clear that a mix of technologies using a range of renewable resources - solar, wind, wave, tidal - are required, along with significant increases in the use of biomass, if these and future targets are to be met (Schmidt 2010, SEAI 2011, DCENR 2012).

At the same time, it has become apparent that lack of enforcement of Part L of the building regulations may have contributed to the poor standards of energy efficiency in buildings (Cotter & Silke 2010).

> "Statistics show that Ireland suffers from having among the worst housing standards in Europe in terms of insulation levels, heating equipment and energy efficiency."— J.P. Clinch and J. Healy (2011)

The National Consumer Council concludes:

> "Conformance with the newly adopted requirements … will be difficult to establish without proper enforcement ... We have concerns that consumers will not be able to rely on the BER [Building Energy Rating] system ratings." (NCA 2008 pp35)

One technology with potential to help governments to achieve their aims and fulfil their obligations with regard to RE is Combined Heat and Power (CHP), also known as cogeneration. Waste heat produced from electricity generation is captured and used, resulting in high overall efficiencies of up to 90% (Carbon Trust 2010) compared with traditional power station efficiencies of only 30-40%. Figure 1 illustrates how this is achieved.

[1] a minimum of 10% is required from the transport sector, 12% from the heat sector and 40% from the electricity sector.

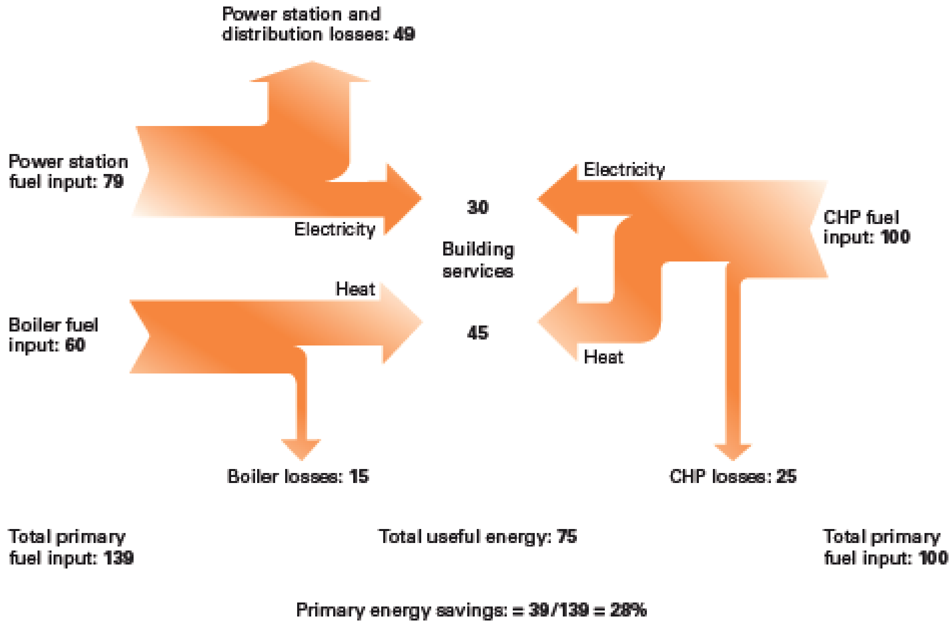

Figure 1 Efficiency and energy savings through CHP compared to conventional heat/power generation (Carbon Trust 2010 pp6)

1.2 Biomass CHP and District Heating

CHP can be operated using a variety of fuels and is an excellent tool for improving efficiencies (by up to 3 times over heat only systems) of conventional fossil-fuelled power stations and for lowering Greenhouse Gas (GHG) emissions (BEC 2012), but only biomass-fuelled CHP can be considered a Renewable Energy Technology (RET). Biomass fuels, derived from plant material[2] or organic waste[3], and usually processed into chips or pellets, have nearly net zero carbon emissions balances, due to absorption of carbon during their lifecycles, therefore offering further reductions in CO_2 emissions compared to fossil fuel CHP. Gaseous products of anaerobic digestion (AD) can also be used.

CHP is often associated with an industrial process requiring high levels of electrical and/or thermal power. Alternatively, the heat generated is used for district heating (DH), a means of distributing hot water to buildings via networks of highly insulated underground pipes for the dual purposes of space heating and hot water supply (see Figure 2). A variety of end-users distributes the heat load more evenly over time. It is typically associated with areas of high-density housing in continental Europe.

[2] E.g. wood, waste wood, biomass crops such as willow, miscanthus, eucalyptus.
[3] E.g. municipal solid waste,slurry/food-waste.

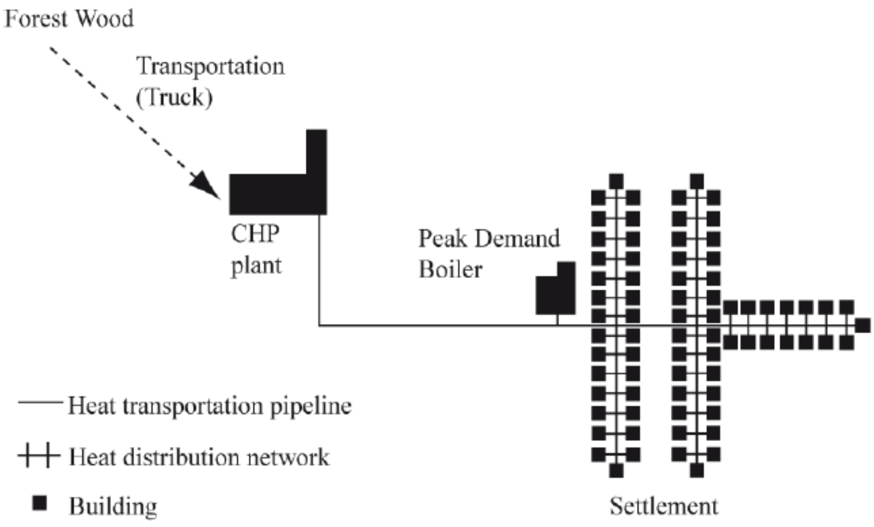

Figure 2 Diagrammatic representation of a wood-fuelled CHP plant with DHN (Schmidt et al 2010, pp4)

A peak demand boiler is used for emergency backup or in tandem with CHP to boost capacity. Customers have individual meters and heat-exchangers to transfer the heat to their (wet) central heating systems. The heavily insulated underground pipeline required for a District Heating Network (DHN) can be costly and because of limits on distances over which hot water can be piped, this, along with plant size, governs the size of area that can be served. High-density housing can therefore be advantageous (Schmidt et al 2010).

The combination of biomass CHP alongside DH has not yet been trialled in Ireland where most development to date has been fossil-fuelled CHP, for individual businesses and production plants, or in biomass CHP for the woodchip industry (SEAI 2011a).

The SEAI (2011), the national organisation for renewable energy, pledges to deliver 12% renewable heat by 2020, and to remove barriers to CHP and DHNs. The Ireland National Climate Change Strategy (DEHLG 2007) set targets of 400 MW_e by 2010 and 800 MW_e by 2020 of installed CHP capacity[4] through a CHP Deployment Programme[5] (CHPDP). Under the SEAI Greener Homes Scheme 2006-8, 52 biomass projects received funding, and despite initial problems[6] and lack of skills and training a number of Irish woodchip and pellet suppliers[7] were established (Hayes 2009). However, the end of the CHPDP in 2011 and Ireland's economic downturn have severely affected further development (Dicken 2008).

[4] There are no specific targets set for biomass-fuelled CHP.
[5] At the end of 2008 total active CHP was 298.7 MW_e.
[6] For example when a shortage of pellets occurred when demand outstripped supply in the winter of 2007 due to the unexpectedly high uptake of the SEI capital grant scheme for wood-fuel boilers.
[7] The largest of these, Balcas, is near the Donegal border in Enniskillen.

Chapter 2. Literature Review

2.1 Introduction

The literature review provides an insight into current thinking and practice on small scale biomass CHP/DHN, and various factors that influence its success.

2.2 Technology

2.2.1 Overview of technologies

Combustion along with steam power is the principle means of converting biomass to power and heat, though recently, techniques such as pyrolysis, gasification, and the Organic Rankin Cycle (ORC) have led to the development of a number of different technologies[8] which improve the viability of small-scale production. A description of these, as outlined in a 2009 literature review of small-scale biomass technologies, is presented in Table 1.

Table 1 Main energy conversion technologies for biomass-fuelled CHP systems (Dong, Liu & Riffat 2009)

Primary Technologies	Secondary Technologies
Combustion producing steam, hot water	Steam engine; Steam Turbine; Stirling Engine; Organic Rankin Cycle (ORC);
Gasification producing gaseous fuels	Internal Combustion Engine; Micro Turbine; Gas turbine; Fuel cell;
Pyrolysis producing gaseous and liquid fuels	Internal Combustion Engine;
Biochemical, biological processes producing ethanol/biogas	Internal Combustion Engine;
Chemical/mechanical processes producing biodiesel	Internal Combustion Engine;

Combustion with a steam turbine is the most developed and widely used engine-type in hundreds of plants operating in continental Europe, though ORC processes are increasingly common (Lenzen 2010, Carbon Trust 2010). These generally operate in the range >5MW_{th}, most of the smaller plants (down to 330kW_e) being AD plants (Carbon Trust 2010).

Scaling down combustion plant presents problems in maintaining efficiency and dealing with the by-products of combustion, as outlined by Dicken (2008), and Dong, Liu and Riffat (2009) who suggest advancements in cleaner technologies like gasification and pyrolysis may benefit small-scale CHP. Because they contribute to decentralised electricity

[8] ORC operates at lower temperatures and pressures than steam and is therefore subject to less rigorous Health and Safety regulation; pyrolysis and gasification offer cleaner alternatives to combustion with fewer pollutants and waste products (Lenzen, 2010)

generation, small to medium scale plants up to $5MW_e$ can also create jobs (Dong Liu & Riffat 2009, Lenzen 2010, WDC 2008), offering useful income and employment in rural areas.

2.2.2 Small Scale Biomass CHP

The definition of small scale CHP varies in the literature from under 100kWe (Dong Liu & Riffat, 2009) to 5MWe (WDC, 2008), while Atkins (2002) report on potential for DH in Ireland concluded "Any new CHP/DH scheme that is installed in Ireland will be classed as a small scale CHP unit, the electrical output of which ranges from 5 kW_e up to about 8 MW_e."

Although gasification and pyrolysis offer the best opportunities for biomass CHP operating in the range $100kW_e$ – $2MW_e$, these technologies are less well developed than others and among the biomass gasification systems commercially available, "there are only a few systems that have been economically demonstrated at a small-scale." (Dong, Liu & Riffat 2009). Barbier (2010) also cautions against gasification technologies, citing lack of evidence on reliability and loss of both heat and power in the event of a breakdown.

Nevertheless, for this study, in anticipation that it will be smaller scale biomass CHP (under $2MW_e$) that suits a small town, gasification will be considered. Companies advertising small-scale biomass CHP plant as commercially available or near to market include:

Table 2 Companies with small-scale biomass CHP on or near to market.

Company Name	Location	Type of plant	Size range of plant (electrical load)	Website
Entimos	Finland	Gasification	1MW-12MW	http://www.entimos.fi/inenglish.htm
Cleanstgas/KWB	Austria	Gasification	125kW, 250kW,	http://www.cleanstgas.com/en/unternehmen.html
Biomass Engineering (BEL)	Wigan, U.K.	Gasification	Modular, 500kW	http://www.biomass.uk.com/
Turboden	Milan, Italy	ORC	600kW-6MW 6MW+ customised	http://www.turboden.eu/en/products/products-chp.php
Ecolink (supplier/installer only)	Grantham, UK	ORC	Unknown	http://www.eco-link.co.uk/chp.html

2.2.3 DHN in Ireland

DH has been slow to develop but recent investment in the Dublin DHN and some small-scale schemes (seeTable 3) hint at change.

A recent report by the statutory body established to promote social and economic development in the West of Ireland, (WDC 2008), found little potential for DHN outside the two largest centres of population in the region, on the basis that only CHP systems with an output of $5MW_e$ or more and a population above 20,000 are appropriate for DH. This ignores Atkins' (2002) recommendations that where natural gas is unavailable, as in County Donegal, see Figure 3 below, DHN may indeed be favourable, and that "a good niche opportunity exists" if fuelled by RE.

Figure 3 The natural gas pipeline in Ireland

[in purple (Bord Gais 2010) adapted, with WDC region outlined & County Donegal highlighted]

2.2.4 DHN in sparsely populated areas

Because of high capital costs associated with infrastructure required for DH, only areas with high heat densities have, until recently, been considered suitable for its application. However, once laid, DHNs are low maintenance and usually outlive the plant supplying the heat: expect a 30-year lifespan as a minimum (WDC 2008, Olsen 2008). Due to increasingly energy efficient housing, existing DHNs serving cities will need additional customers in the more sparsely populated suburbs. This means their application in less heat intensive area densities has been increasingly scrutinised (Olsen 2008).

A research study led by the International Energy Agency (IEA) (Zinko et al. 2008) concludes that the availability of new technologies and methodologies means DH can now be considered for lower density areas.

> "Expressed in terms of heat densities, we believe that areas with a heat density of 10kWh/m^2.yr or with line heat demand of 0.3 MWh/m.yr can be economically served by district heating." (Zinko et al p. vii, 2008)

This differs significantly from the high heat density of 0.8MWh/m/yr usually assumed necessary for the planning of DHN (Zinko 2008).

This same IEA study analyses existing applications of sparse DH to illustrate the main problems and heat losses associated with delivering lower density heating-demand, and costs various layouts of the distribution network to reveal the optimal for each. House-to-house connections[9], can reduce costs, but are considered less suitable for retrofit because of disruption to properties and gardens.

The study recommends that heat from DH systems could be better used in future if household appliances such as washing-machines were redesigned to utilise it, thereby reducing electricity demands, boosting the decreasing market for heat, and further reducing emissions given the higher primary emissions associated with electricity.

The same research concluded that with currently available technologies, it is not environmentally beneficial[10] to use DH with a lower line heat density than 0.2 MWh/m/yr.

Another suggestion favouring areas with low population densities, is that CHP/DHN could be a cheaper and more effective alternative to reducing emissions from older housing stock than retrofit (Orchard 2008).

There are also increasing numbers of successful examples of (heat only) small-scale woodchip-fuelled DHNs in the UK and Ireland serving less than 100 homes and with an output of under 1MW_{th}. Some examples of these are presented in Table 3 below.

Table 3 Heat-only small scale biomass-fuelled DHN

Name	**Location**	**CHP**	**DHN**	**Size - kW_{th}**	**Website**
Kielder	Northumberland, UK	X	√	300	[11]
Glenshallach	Oban, Scotland	X	√	650	[12]
Mitchels Boherbee Regeneration Project	Tralee, County Kerry, Ireland	X	√	1000	[13]
Camphill Community	Clanabogan, Co. Down, N. Ireland	X	√	320	[14]
Cloughjordan Ecovillage	County Tipperary, Ireland	X	√	1000	[15]

[9] These reduce the length of pipeline required
[10] based on calculations of Global Warming Potential for a typical heat source using 20% fossil fuel in Sweden
[11] http://www.forestry.gov.uk/pdf/BS_casestudy_Kielder.pdf/$FILE/BS_casestudy_Kielder.pdf
[12] http://www.scotland.gov.uk/Publications/2009/03/20155542/33
[13] http://www.seai.ie/Publications/Renewables_Publications/The_Mitchels_Boherbee_Regeneration_Project.pdf

[14] http://www.camphillclanabogan.com/index.php?Environment-Biomass-District-Heating-130

[15] http://www.thevillage.ie/index.php?option=com_content&view=article&id=60&Itemid=17

2.3 Biomass and Forestry

The availability of a reliable, long-term and local supply of woodfuel is an essential ingredient in the success of small-scale biomas CHP (WDC 2008).

2.3.1 Overview of bioenergy market

The bioenergy market in Ireland has been boosted by the renewable targets set for 2020. The 16% overall target is divided into heat (RES H), electricity (RES E), and transport (RES T) sectors, and the bioenergy contribution to these is projected by the SEIA as outlined in Table 4.

Table 4 Contribution of biomass to Ireland's 2020 RE target (Caslin, 2012)

Sector	2020 overall target (ktoe)	% biomass	ktoe Biomass	GWh biomass
RES-E	2 665	5.6	149	1733
RES-H	4 126	9.7	400	4652
RES-T	4 910	8.6	345	-
Total	11 701	7.6	894	6385

Additional targets including 800MW_e of CHP by 2020, anticipates a mix of forest pulpwood, straw, fuel crops[16] and slurry to fulfil future requirements (Caslin 2012).

However, sustainable production methods are essential to ensure that the zero emissions balance, along with other issues such as food security and biodiversity, is not compromised. For these reasons, among others, Lenzen's literature review of electricity generating technologies (2010) concludes that biomass derived from residual forestry products is preferable to first generation timber or energy crops as a fuel.

2.3.2 Forestry and wood fuel

The state forestry commission with responsibility for state owned forest in Ireland is Coillte. Privately owned forestry is administered by Teagasc, the Agriculture and Farm Development Authority.

Despite having some of the lowest forest cover in Europe, just under 11% (Casey and Ryan, 2012), good potential for growth exists in the private sector and cluster analysis has been developed by Teagasc to help in identifying areas which have a local forestry resource that

[16] E.g. willow, miscanthus, eucalyptus.

is suitable for local use (Phillips, 2012). Ireland has a dispersed, largely rural population and agriculture is a principal industry. Private forestry, encouraged by a programme of grant-aided planting through the 1990's, enabled farmers to diversify and improve their income. These forests are now ready for first thinning (Kent 2012).

Thinning is the progressive removal of trees between years 12 and 35, to ensure that the final crop is of good quality and profits are maximised. Private sector thinnings (pulpwood), have few high end uses, yet despite an anticipated increase in volume from 22,800 ha in 2011 to 49,400 ha in 2028 (Kent et al., 2011), a supply/demand shortfall is forecasted by 2030 (Phillips 2012) due to challenges in mobilising the resource. There are concerns that declining afforestation since 1997 may lead to shortages in supply[17] from 2035 (Casey and Ryan, 2012). The author attended the 2012 Bio-Energy Ireland conference at which some of the issues facing forestry, summarised in Table 5, were presented.

Table 5 Challenges in mobilising the existing private forestry resource to meet 2020 targets and possible solutions (Phillips 2012, Kent et al.2011, Casey & Ryan 2012)

Challenges	Possible Solutions
Forest owners unwilling/unable to thin plantations	Promoting awareness, guidance and education re the importance of thinning
	Introduce a legal requirement for management
Lack of collaboration among owners	Promote collaboration as a means of sharing contractors
Poor access, lack of forest roads	Prioritise a forest roading scheme; ensure future planting satisfies accessibility criteria.
Small plantations – contractors unwilling to thin small areas	Promote collaboration as a means of sharing contractors/ introduce legal requirements
Lack of experience in sales, logistics and certification procedures in the supply chain	Set up long term supply contracts; promote education/support for training of operatives
Long term shortfall in supply versus demand	Plant a range of energy crops; Leverage additional biomass by harvesting residues, stumps, brash[18]

2.4 Regulatory and Legislative Environment

As outlined above, Ireland is committed to achieve targets for RE generation by the year 2020. Chief legislative instruments to enable this are:

- The Ireland National Climate Change Strategy (DEHLG 2007) set targets of 400 MW_e by 2010 and 800 MW_e by 2020 of installed CHP capacity[19] through a CHP

[17] And even a longer term possibility that Ireland's forests could become net emitters of carbon
[18] Brash is the twiggy residue from clear-felling and can be bundled for fuel.
[19] There are no specific targets set for biomass-fuelled CHP.

deployment programme (CHPDP). At the end of 2008 total active CHP was 298.7 MW_e. This programme was withdrawn in 2010.

- The SEAI (2011) pledged in its 5 year strategic plan to deliver 12% renewable heat by 2020, and to remove barriers to CHP and DHNs.
- Part L of the Building Regulations 2008 specifies all new buildings must have at least $10kWh/m^2$/year of heating and hot water use provided from RE sources (Ecoheat4EU, 2011a)
- The Renewable Energy Feed-in Tariff, REFIT 3, announced in March 2012, guarantees 14c/kW payable for electricity generated from biomass over 15 years or to 2030, a significant financial support to biomass CHP. It aims to add $310MW_e$ capacity to the Irish grid so that biomass technologies can contribute to the RE target for 2020, with:

> "a total of 200MW of this being new capacity in (AD) and solid biomass areas. Of this, 150MW will be high efficiency combined heat and power (CHP), using both (AD) and … thermochemical conversion of solid biomass" (DCENR 2012a)

While these measures are supportive of biomass technologies they fall short of more targeted legislation and more robust financial supports that are in place in other European countries (Ecoheat4EU, 2011).

In the UK, for example a renewable heat tariff (RHI) has recently been introduced. This is of special concern to the biomass industry in Ireland as potential investors here are likely to favour Northern Ireland where returns on investment will be higher (Caslin 2012).

At the local level, Tralee Town and Clare County Council have been at the forefront of championing biomass technologies, engaging with the public, and in seeking to influence national policy.

In its County Development Plan 2008-2012 Donegal County Council states its policy on bioenergy:

> "to support initiatives, which raise awareness and/or increase the use of this important renewable energy source."(DCC 2008 Ch7.5)

2.5 Public Attitudes /Perceptions

Public opinion and attitudes towards RE are important factors in its uptake, while opposition can add significantly to the set-up time and costs, or ultimately result in planning permission refusals. RE developers are therefore increasingly interested in engaging with local communities in order to gain their acceptance and avoid costly delays (Walker et al 2010), As happened with recent proposals for a 70MW plant in Shannon, County Clare and a 15MW plant in Rhode, County Offaly which have both been delayed through opposition encountered at planning stages (Coughlan 2012).

Atkins (2002) is frequently cited in his use of the failure of the Ballymun DH scheme in Dublin in the 1960's as the reason for public mistrust of DHNs. As recently as 2011 the report was referenced to explain that development of DHN is hampered "due to a lack of knowledge and understanding among the general public" (Ecoheat4EU 2011)

Small-scale biomass CHP lends itself ideally to community-led RE projects which have been demonstrated to be the most successful across Europe (Devine-Wright 2005). However, as supporters of Aman-al-Tawe wind farm discovered, opposition can arise from *outside* the community served by the project (Hinshelwood, n.d.), so engaging with neighbouring communities not benefiting directly from the proposed scheme, might be useful.

2.6 Opportunities and Barriers to biomass CHP/DHN

O'Cleirigh (2009) cites the following major obstacles to the development of district heating:

• the mild Irish climate;

• unfavorable economic returns;

• the need to achieve socio-technical change;

The International Energy Agency (IEA) and Ecoheat 4EU (2011) project, both committed to promotion, research and development of DH in Europe, have published a comprehensive analysis of the challenges and opportunities particular to Ireland, a summary of which is presented in Table 6.

Table 6 Challenges/Opportunities for DHN in Ireland (Ecoheat4EU 2011)

Drivers/Opportunities	Challenges /Barriers	Possible Solutions
Energy from Renewables requirement within Part L of Building Regulations	The inability to trade surplus power from CHP plants	Review Electricity Regulation Act 1999
Proposals for DH systems in Dublin and Cork from waste fired CHP	Lack of legislation and policy wrt ESCOs, DHN and planning permission	
Using heat from combustion of biomass, i.e. wood chip, wood pellets and bio crops	Lack of understanding	Successful case studies/demonstration projects

Using AD or geothermal heat.	Lack of year round heat demand	Finding a summer demand for heat, perhaps to drive absorption chillers
Introduction of the carbon tax.	Lack of joined up thinking between stakeholders	
CHP deployment Scheme[20]	Economic reasons - high CapEx, access to finance.	Financial support or tax incentives.
Cost savings through energy efficiency	Low density development	Planning for and building higher density developments
Security of supply – fluctuations in fossil fuel prices.	Assessment of potential heat demand.	

2.7 The Electricity Market

Unless a localised demand for electricity can be established a connection to the grid is required and a customer found for the exported electricity. There is no option to set up a local distribution network since the Electricity Regulation Act (ERA 1999) prohibits private wire networks (O'Cleirigh 2009).

For plant under $10MW_e$, connections are made to the distribution grid and an electricity distribution company[21] becomes the purchaser. Connecting to the grid for plant up to $1MW_e$ is quicker and simpler than for larger plants and should be completed within 3 months, with no license required.

> "A person proposing to generate electricity from a class of generating station referred to in Article 4(2)(b) shall automatically stand duly licensed to generate electricity pursuant to this Order" (ERA 1999).

This is advantageous to small scale CHP.

2.8 Methodologies

The Combined Heat and Power Association (CHPA, 2012) provides a comprehensive checklist for conducting a CHP/DHN feasibility study, reproduced below:

- space heating, cooling and hot water loads
- phasing of the development
- optimum route and size of pipes for the network
- locations for plant room(s)
- length of network, height of buildings, local topography
- network heat losses

[20] Now defunct, see above.
[21] For generators over $10MW_e$, the electricity is bought by the Single Electricity Market

- type and scale of connections
- thermal storage
- data on load curves, base and peak loads
- types of fuel and supply chains
- space for delivery, storage and handling of bulky fuels
- other heat production opportunities that could augment the project
- future proofing

Action Energy[22] (2004) provides a set of good practice guidelines and a worked example for sizing plant and viability.

A variety of modelling techniques and software has been developed for optimal sizing and locating CHP/DHN. Software packages such as EnergyPro and Retscreen 4 allow a large number of parameters as inputs.

Abd Jamil et al. (2007) use the Strathclyde Domestic Energy Modelling tool to assess the energy demand of a residential area for an MSc project. This tool is based on the U.K. Standard Assessment Procedure (SAP) and inputs include the age and types of housing plus any energy efficiency improvements affecting demand.

Flexenergy (2012) and Logstor (2012), companies who specialise in supplying the highly insulated pipes for DHN, provide online calculators to enable pipe lengths and distribution heat losses to be compared for different lengths, sizes and types of pipe.

2.9 Summary and Implications for the research rationale

The need to perform a preliminary, location-based assessment of the viability of CHP/DHN forms the basis of the rationale behind this study.

The economics of a CHP/DHN project, while clearly important, is not the only factor to be considered in assessing its viability. Other factors such as location, a reliable supply chain for the fuel, public acceptability and the practicalities of finding a suitable plant, along with optimising the layout of DHN could all be limiting factors.

The location chosen for the study needs to satisfy at least these criteria:

- at least one building with constant, high demand for heat;
- biomass supply chain within a 30 mile radius;
- Lack of access to natural gas;

[22] now the Carbon Trust

No single model or methodology was found that could be adopted. Existing modelling software requires more detailed inputs than will be available for this study, some do not allow for biomass gasification as a technology. None consider public acceptability. A methodology incorporating essential elements of methodologies listed in section 2.8 was therefore adopted.

2.10 The Rationale for this study

Ireland's dependency on imported fuel and current reliance on peat for energy security is not sustainable, either from a competitiveness or environmental perspective (SEAI 2011). Home-grown biomass is able to contribute to the future security of supply as well as an important part of the strategy to reduce CO_2 emissions (SEAI 2011).

Good Practice Guide 388 (Action Energy, 2004), states that in terms of reducing building related CO_2 emissions, CHP can be the single biggest measure to undertake. Buildings are accountable for 42% of Ireland's total CO_2 emissions (Howley et al. 2011) and this can be addressed in part through increasing CHP and DHN.

Fluctuations and long term increases in the price of crude oil as illustrated in Figure 4 have a significant impact on the cost of heating homes in areas without access to the natural gas network.

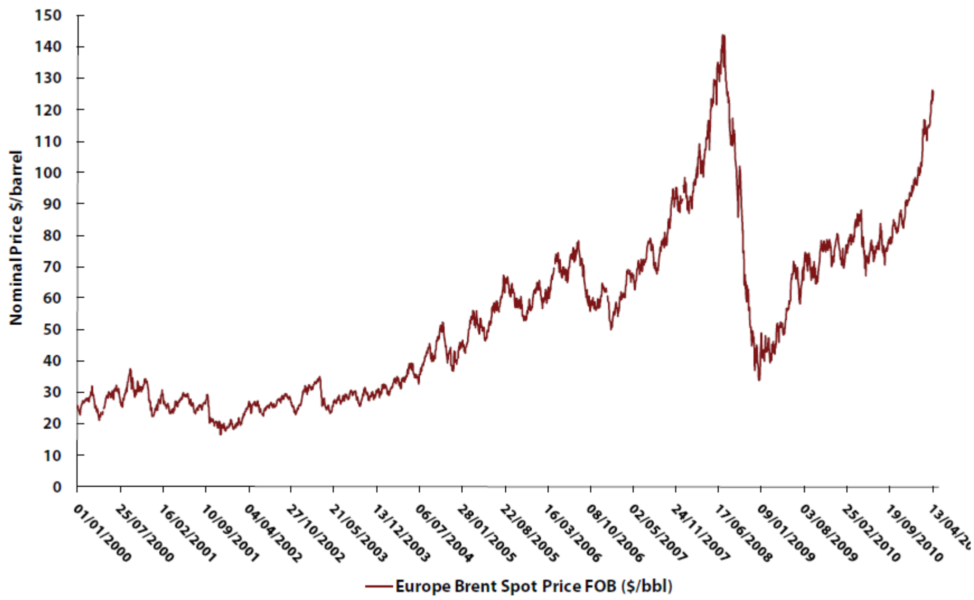

Figure 4 The rise in Crude Oil Spot Prices 2000-2011 Source: U.S Energy Information Agency 2011 as presented by SEAI (2011 pp16)

New developments suggest small scale CHP with DHN in lower density areas may be viable and small scale biomass CHP plants are becoming commercially available. It is therefore possible that small scale biomass CHP/DHN could provide a viable option for heating Ireland's small towns and villages, offering advantages in terms of security of supply and employment, particularly in rural areas.

There appears to be a mismatch between the view that biomass CHP/DHN is unsuited as an energy service for small towns in Ireland, with advances in technologies and changing circumstances that have occurred in recent years. This study hopes to contribute to the research agenda by conducting a location-based preliminary assessment of the viability of small scale CHP/DHN, before making recommendations. The results should be sufficiently robust to indicate whether full scale feasibility studies might be worthwhile.

2.11 Aims and Objectives

Having outlined the rationale behind the research, the aims and objectives are now presented. The main research aims are:

To conduct a preliminary assessment of the viability of biomass-fuelled CHP with DHN as an energy service for a small town in County Donegal.

To assess the viability of the project in terms of: supply chain, heat demand, costs and returns, public acceptability, legislation and regulation.

Six objectives were set in order to meet these aims:

To identify a suitable location on which to base the assessment;

To establish the presence of a reliable supply chain of biomass;

To estimate the heat demand of the study area;

To review the technologies available and choose one that is appropriate;

To establish potential customer numbers and guage public attitudes towards biomass CHP and DHN in the study area, by means of a questionnaire survey;

To estimate potential reduction in Greenhouse Gas Emissions.

Chapter 3. Data Collection Methodology

3.1 Overview

Table 7 below summarises the information/data gathering techniques proposed in order to fulfil the project's objectives.

Table 7 Summary of information and data gathering methodology

Information/Data required	Information/data gathering techniques proposed
A suitable location for the study.	Must satisfy the criteria identified in section 2.9
Energy demand for space heating and hot water demand of any "anchor buildings".	Initially, seek primary data from the building managers in the form of utility bills, annual usage figures. Secondarily, use published benchmarks or case studies as estimates and obtain floor areas.
Residential energy demand for space heating and hot water.	Questionnaire Survey of residents, floor areas.
Distance over which the DHN will need to be laid	Measure distances involved.
Evidence for a local biomass supply chain.	Interview the local forestry development manager at Teagasc.
Numbers of potential customers.	Questionnaire survey of residents.
Identify commercially available, small-scale CHP plant,	Seek information, costs and specifications from CHP plant manufacturers.
Costs and Income	Obtain estimates for costs from contractors and manufacturers. Otherwise, use published case studies to make reasonable estimates.
Public attitudes to CHP/DHN as a potential energy service in the locality.	Questionnaire survey of residents.

3.2 Methodology

3.2.1 Choice of Location

The location was chosen to satisfy the criteria identified in the literature survey:

- lack of access to the natural gas pipeline, see Figure 3 p15;
- presence of a year round heat demand;

- the possibility of a local wood supply;

Also, from the author's perspective, close enough to home to maximise the time available to conduct the research, including a questionnaire survey.

Stranorlar is a small town in County Donegal, a twin town to Ballybofey located in the Finn Valley in East Donegal, close to the border with Northern Ireland, pinpointed in the maps in Figure 5.

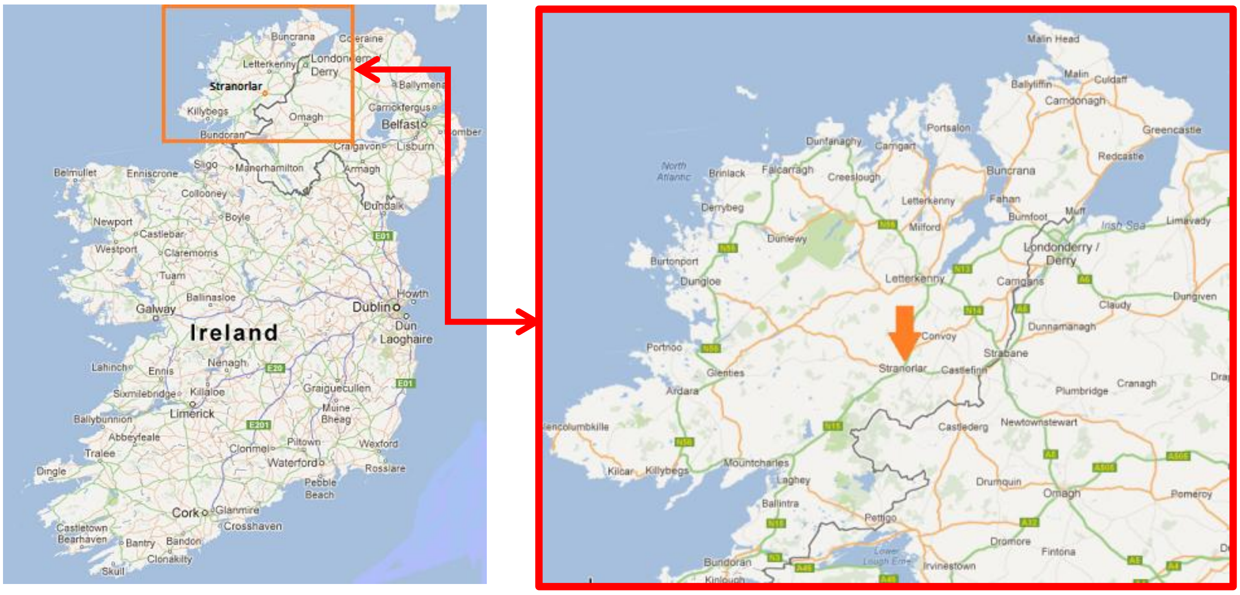

Figure 5 Location of the study area, (Google, 2012)

Stranorlar is primarily a residential area and home to two secondary and two national schools, a primary healthcare centre and some small retail businesses. Also, and importantly for this study, there is a 50 bed hotel with private leisure centre and 12m pool, a 25m swimming pool (currently under construction) and a small hospital specialising in care of the elderly, on the outskirts of town. A sawmill in the town indicates a local timber supply and there are forestry plantations in the vicinity. Housing is a mixture of types and ages, including old and new social housing estates, one-off detached houses and bungalows, private developments and one apartment block.

A sub-section of the town including the three anchor buildings was chosen as the study area, in order to fit in with time and workload constraints, and to minimise the potential for stretches of DHN with little or no heat demand (see Figure 20, p.46).

3.2.2 Calculating heating and hot water demand of the "anchor buildings".

Requested building managers of the hospital and hotel to supply annual or preferably monthly space heating and hot water costs. In the case of the swimming pool (under construction) requested predicted energy use.

3.2.3 Residential energy demand for space heating and hot water

Established ages of the houses (to allocate a BER rating), patterns of use, fuel types and energy efficiency upgrades by means of a questionnaire survey.

Estimated floor areas via a combination of measurements on the ground where practicable, large scale maps (1:10 000), and Google Earth.

3.2.4 Distance over which the DHN will need to be laid

Defined the study area and located the CHP plant. Used large scale maps (1:10 000) to design a possible layout for the DHN and calculated linear metreage. Average distances for each property to connect to the main pipeline were assessed.

3.2.5 Evidence of a potential local biomass supply chain.

Interviewed the forestry development manager at Teagasc, to obtain relevant information about long-term availability of a local supply. Used published figures to support this.

3.2.6 Numbers of potential customers.

A questionnaire survey was designed to establish the level of interest in joining up to a biomass CHP/DHN and understand what the main influences might be.

3.2.7 Identify commercially available, small-scale CHP plant

Contacted the manufacturers of small-scale biomass CHP plant identified in Table 2 to collect information on capital costs, running costs and specifications, in particular, on fuel efficiency ratios.

3.2.8 Costs and Income

Capital outlay, running costs and income from heat and electricity sales were calculated from estimates obtained from manufacturers, suppliers, utility companies and other primary sources where possible. When not available, reasonable estimates were based on comparable case studies and/or published benchmark figures.

3.2.9 Public attitudes to CHP/DHN as a potential energy service in the locality

Assessed using a survey questionnaire. The methodology and results for this are presented separately in Chapter 4.

Chapter 4. Conducting a Survey Questionnaire

4.1 Rationale and design of the survey

4.1.1 Rationale behind the survey

A survey questionnaire was designed in two parts to gather data as outlined in Table 1 above, with Part 1 focussing on the data required to assess the energy use of the residential sector. While some of the results from Part 1 are presented in Chapter 5, the questionnaire also presented the opportunity to gather some secondary data that will prove useful in the analysis that is presented in Chapter 6. Part 2 of the survey was constructed specifically to assess public attitudes to CHP/DHN.

4.1.2 Design of the survey

Appendix B contains an annotated copy of the questionnaire survey to include the codes used for analysis and the results.

Due attention was paid to layout of the questionnaire and guidelines as to the type and phrasing of questions as outlined by Fink (1995), in order that responses should reflect the views of the participants as accurately as possible (see 4.3.2).

Age bands of the houses were chosen specifically to correspond with those used for the BER[23] System.

4.2 Sampling strategy

4.2.1 Sampling and statistical significance

In order to establish statistical significance for a small population and to generalise results from the sample to the whole population (in this case to 347 households), probability sampling would ensure a representative sample is selected to participate in the survey (Fink 1995).

Israel (2012) proposes a sample size of 78 (actual respondents) to allow a +/-10% accuracy for a population of 350. However, normal distribution is also a pre-requisite for conclusions drawn from probability sampling and in order to employ statistical techniques such as regression and covariance, a minimum sample of 200-500 is required (Fink1995).Lund (2010), suggests that for population sizes of less than 350 the *entire* population would need to be surveyed in order to establish significant levels of confidence.

[23] Further details about the BER and reasons for this choice follow in Section 5.2

A comprehensive survey of all 347 households is not practicable within the time and resource limits of this MSc dissertation, so an alternative is required.

4.2.2 Non-probability Convenience Sampling

Non-probability convenience sampling refers to the most convenient way to recruit participants to the survey (Fink 1995) and is chosen on the basis that it is straightforward and achievable within the context of available resources. For this study it means participation by any resident willing to take part, with the aim of obtaining a 10-15% response rate.

A postal survey was considered but a pilot test of the questionnaire suggested that participants' lack of familiarity with the concepts meant that a verbal explanation was required, so a door-to-door survey was chosen.

4.2.2.1 Advantages of the method:

- "(non-probability sampling) is appropriate within the context of exploratory research, i.e. to discover if an issue even exists" (Lund 2012). This is especially relevant to the collection of data on public attitudes and perceptions where the aim is to discover if perceptions and attitudes to CHP/DHN can be considered a barrier to its development.
- It can be considered as an ethical approach to finding out if the issue is worth examining in more depth – allowing as it does for voluntary participation in the survey (Lund 2012, Fink 1995).
- Another advantage discovered during the survey is that additional qualitative data can be gathered by noting respondents' verbal comments.

4.2.2.2 Disadvantages of the method

The results may not be representative, undermining the possibility of extrapolation to the wider population. Only descriptive statistics such as the mean and distribution are employable, statistical tests such as regression and covariance are not (Israel 2012, Fink 1995).

4.2.2.3 Minimising the disadvantages

For Part 1 of the survey, the results can be compared with other sources of information to validate them. For instance, the age given for a house in a block of houses can be confirmed w.r.t. historical maps and other participants; types and patterns of fuel use can be compared with results from other surveys; occupancy levels and floor areas can be compared with national statistics.

For Part 2, extreme care must be applied in extrapolating the results to the wider study area. Only hypotheses such as "***if*** this sample were representative of the whole, then it would indicate x or y" can be made.

4.3 Conduct of the Survey Questionnaire

The survey was conducted with due regard to bias and reliability.

4.3.1 Bias

Results may be biased, i.e. favouring one section of the population over another. Whilst precautions against bias can be taken, this is more important when probability sampling (Lund 2010).

4.3.2 Reliability

For results of the survey to be reliable they must accurately reflect the views of those taking part (Fink, 1995). Results are less likely to be reliable if responses are given to leading questions (or perhaps, to a student research survey rather than to an actual feasibility study).

While questionnaire design has an important role to play in maximising reliability of the responses, its conduct is equally important.

A number of strategies were therefore employed, over the three months taken to complete the survey, including:

- conducting the survey at different times of day, to capture a cross section of occupants by age, gender and employment status;
- using the same introduction to each prospective participant;
- using the same written piece and images to describe biomass CHP and DHN;

Nonetheless, it is acknowledged that the following issues could compromise the reliability of the data gathered:

- Gender of the researcher – this may influence responses in some cases.
- Although a written description of biomass CHP/DHN was read to participants, different levels of understanding and interest in the project meant conversations between the researcher and respondents during the interview process varied.

4.4 Results and Analysis of the Questionnaire Survey

A more detailed analysis of the results presented in Appendix B and Appendix1.1 follows, beginning with an overview of the sample make-up, followed by results from Part One of the survey. Data relating specifically to assessing residential energy demand is analysed in greater depth in section 5.2.

This chapter concludes with presentation and analysis of data regarding attitudes and opinions to CHP/DHN collected in Part Two.

4.4.1 The Survey Sample

47 households agreed to take part.

The balance of female (68%) to male respondents (32%) is skewed, an example of the bias that can occur in convenience sampling. Even when a man was present it was always[24] the woman who completed the questionnaire[25]. However, instances in which the respondent was both bill-payer and controller of the heating and hot water systems, were identical for both male and female respondents at 93%, and more important than the male/female bias is whether the respondent is the decision-maker regarding the choice of heating system.

4.4.2 Part One - results and analysis

Findings regarding demographics of the sample's domestic heating and hot water use:

Respondents were well dispersed through the age ranges as illustrated in Figure 6 below, with 49% home owners, 34% council tenants and 17% private tenants.

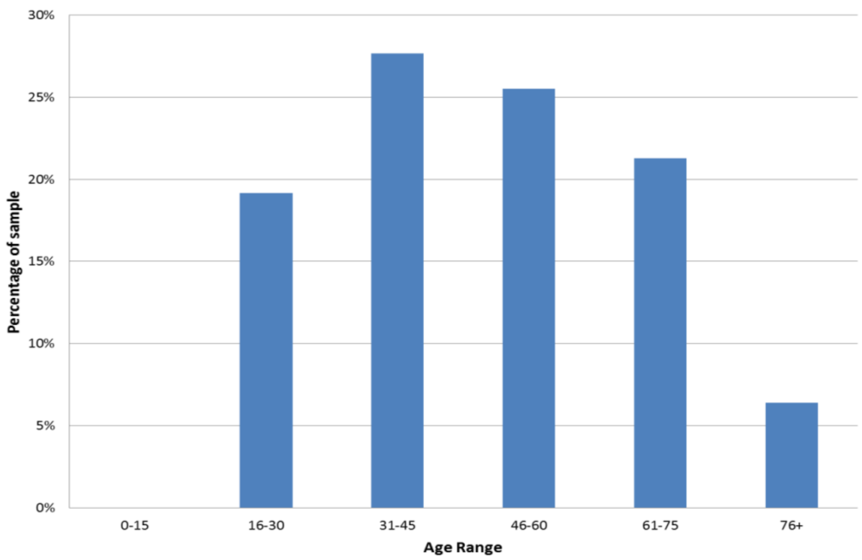

Figure 6 Age range of respondents[26]

[24] in all cases bar one
[25] this may be another example of bias due to the gender of the researcher.
[26] Age ranges on the survey questionnaire overlapped due to author error – it is therefore assumed that the lower age range would have been chosen by anyone whose age lay on the overlap - age ranges have therefore been adjusted for the purposes of analysis.

The average number of occupants in each household is 2.7, slightly lower than the national average of 2.81 in 2006 (O'Leary et al. 2008).

Only one respondent had no central heating, citing the disruption it would cause to the house as the reason.

Of the remaining households[27], 42 use kerosene for central heating, with coal and turf used by 7 and bulk LPG[28] by 3. 37 households use some form of secondary heating fuel (predominantly coal and wood), with electricity and oil the primary means of heating water[29] as illustrated in Figure 7 below. One pensioner relied on an electric heater as "we get free electric in these houses[30]".

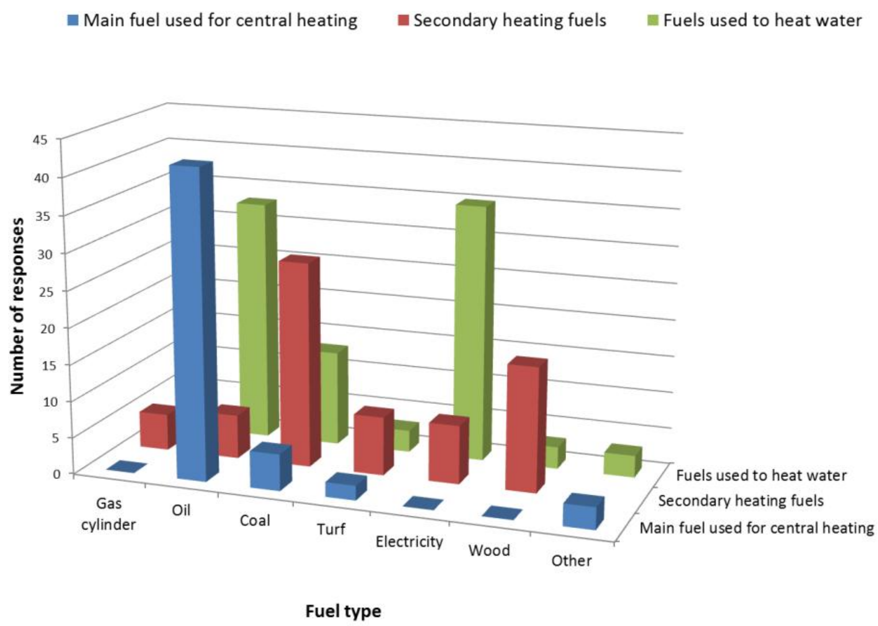

Figure 7 Fuels used for central heating, space heating and hot water

The ages of houses in the sample are distributed as shown in Figure 8, with over 75% built within the past 40 years.

[27] The slight disparities are accounted for by the use of multi-fuel central heating systems.
[28] Liquified Petroleum Gas, used in the apartment block only.
[29] This does not include fuels where the water is heated specifically for an appliance such as an electric shower, a dishwasher etc.
[30] This is part of the Household Benefits Package for older people and others and has implications for uptake of DHN by this group

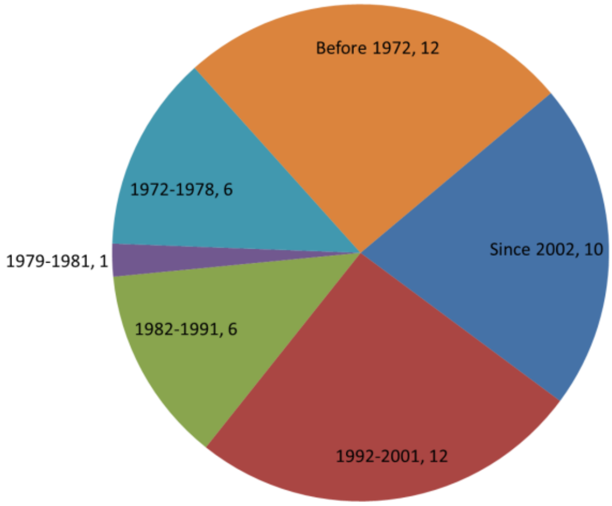

Figure 8 Age bands showing the number of houses in the sample in each

Seasonal and weekly patterns of central heating and hot water use were sought primarily for comparison with the patterns assumed for the BER, and are presented in Chapter 5.

4.4.3 Attitudes and perceptions – results and analysis

Findings from Part 2 of the survey on respondents' thoughts about biomass CHP/DHN:

The majority of respondents (74%) had never heard of this type of energy service, so their reactions were based entirely on the information they were presented with during the survey. First reactions were mainly positive as seen in Figure 9.

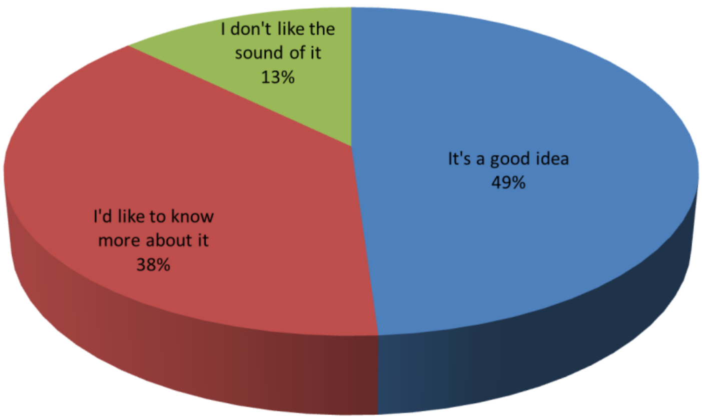

Figure 9 First reactions to the idea of biomass CHP/DN as an energy service

Age has a significant influence on first reactions in this sample as shown in Figure 10 below with the 45s and under most likely to think the service is a good idea, and the 46+ age group more likely to require more information.

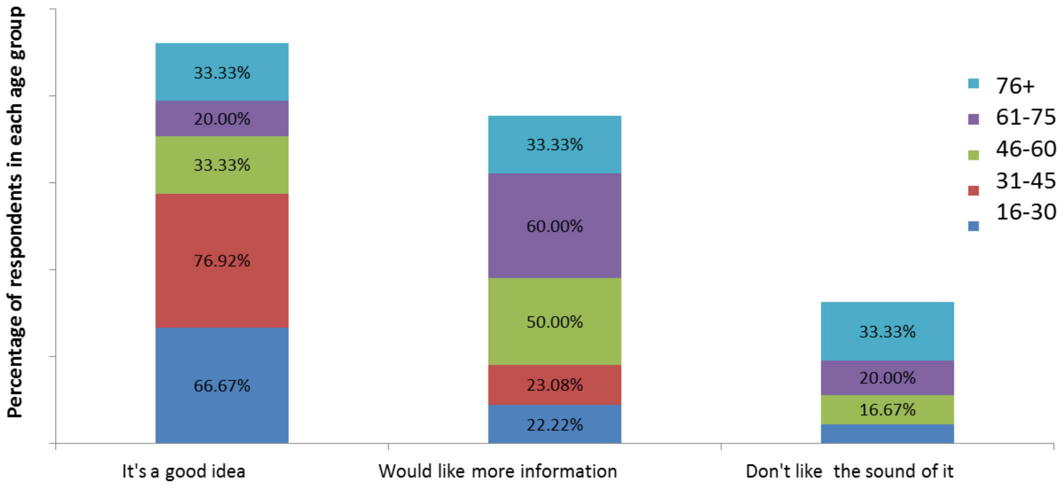

Figure 10 First reactions to the idea of biomass CHP/DHN

In general, levels of interest in connecting up to the energy service were high, with only 9% of respondents not interested and 23% undecided. The majority was either interested or very interested, as illustrated in Figure 11 below.

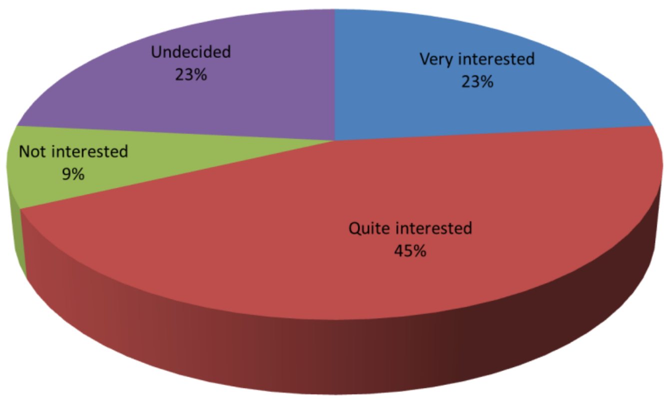

Figure 11 Levels of Interest in connecting to biomass CHP/DHN as an energy service

To determine the effect that previous knowledge[31] of biomass CHP/DHN had on these responses, comparisons were made and are illustrated in Figure 13 below.

[31] Information was sometimes volunteered about the source of this previous knowledge as either the media, experiences abroad, or work/study.

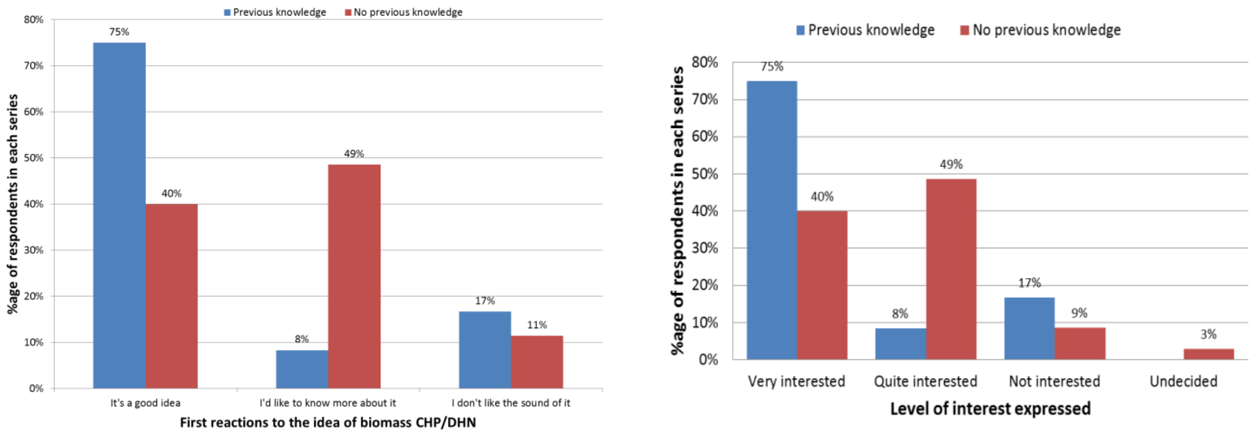

Figure 12 How previous knowledge influences first reactions to and levels of interest in biomass CHP/DHN as an energy service

Overall levels of interest in joining the scheme between the group who had previously heard of the service and those who hadn't are small (83% and 89% respectively), the main difference being that those with previous knowledge were more likely to think it a good idea, and their responses more clear-cut, with 75% very interested and 17% not interested. Those who had never heard of the service were more likely to want to know more about it and to be less committal, as in quite, rather than very, interested.

The issue of greatest concern is cost, with 42 respondents selecting this response, as illustrated in Figure 13 below. Using woodchip and disruption to local roads were of low concern, the latter elicited comments like "look at the state of them!" or "they're always being dug up anyway".

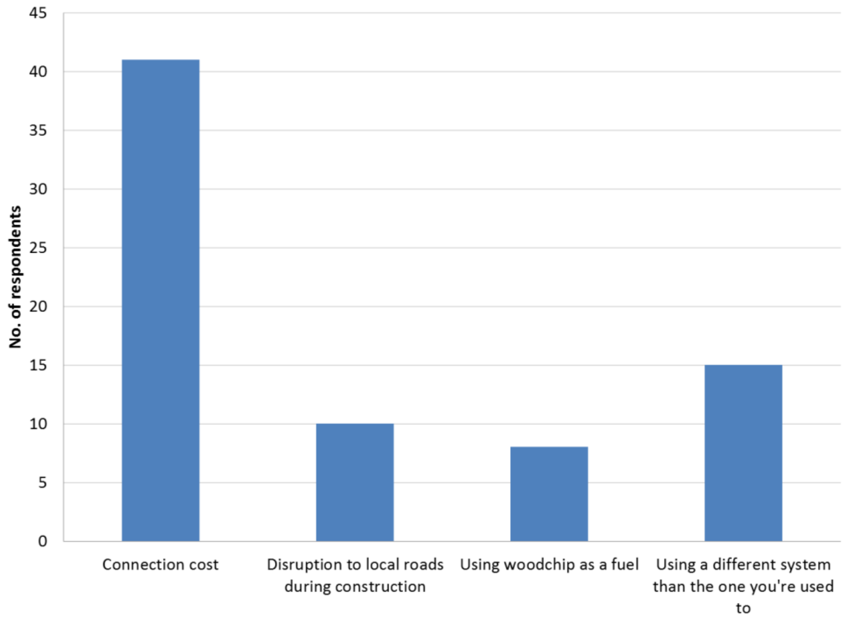

Figure 13 Choice of response as to respondents' concerns about biomass CHP/DHN

Using a different system was of moderate concern, and this was found to be age-related, (see Figure 14) with thirteen of the fifteen aged 46+.

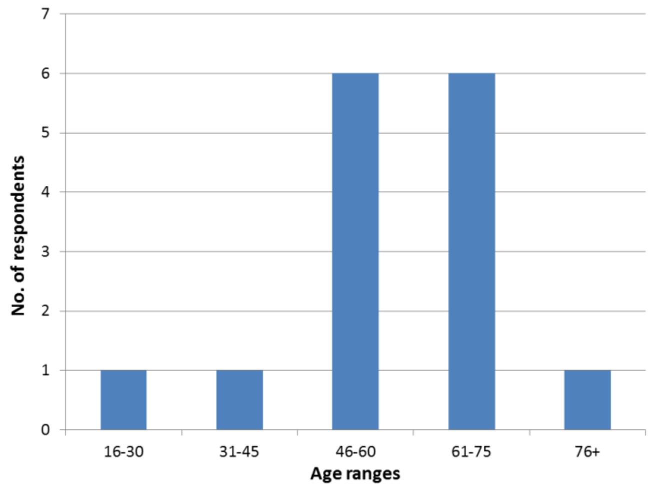

Figure 14 Age range of those who expressed concern about using a new system

Participants were presented with various factors, see Figure 15 below, and asked to rate how these might improve the chance of their joining the scheme. There was broad agreement across the sample that local job creation would be the most important, followed by reinvestment in the local community. The meaning of "Energy Rating" often needed to be explained to participants, so reliability of responses to this question is uncertain. Availability of extra space in and around the home was least important, being preferred[32] by residents in smaller houses with limited outdoor space.

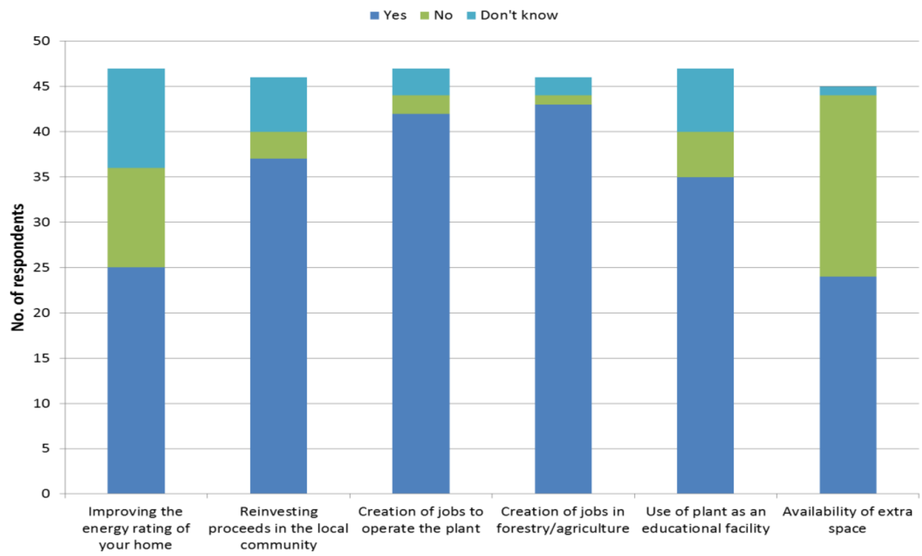

Figure 15 How certain factors may improve peoples' attitudes to joining up to the energy service.

[32] As noted by the researcher.

While connection costs were a major concern (see Figure 13), high fuel costs were also high on the agenda. The type of sentiments expressed are revealed in comments[33] such as:

“they’d need to do something what with the price of oil”

“I have to be very careful with the oil, I’ve only got my pension”

“We only put the oil on in the evening, it’s that dear.”

It is therefore unsurprising that a reduction in heating bills could persuade people to switch to biomass CHP/DHN (see Figure 16 below), with all respondents saying they would if fuel bills were 30% lower. In this small sample there was even one respondent who was keen enough on the idea to pay *more* for the service, and six who would swap even if prices stayed the same, indicating motivations other than costs.

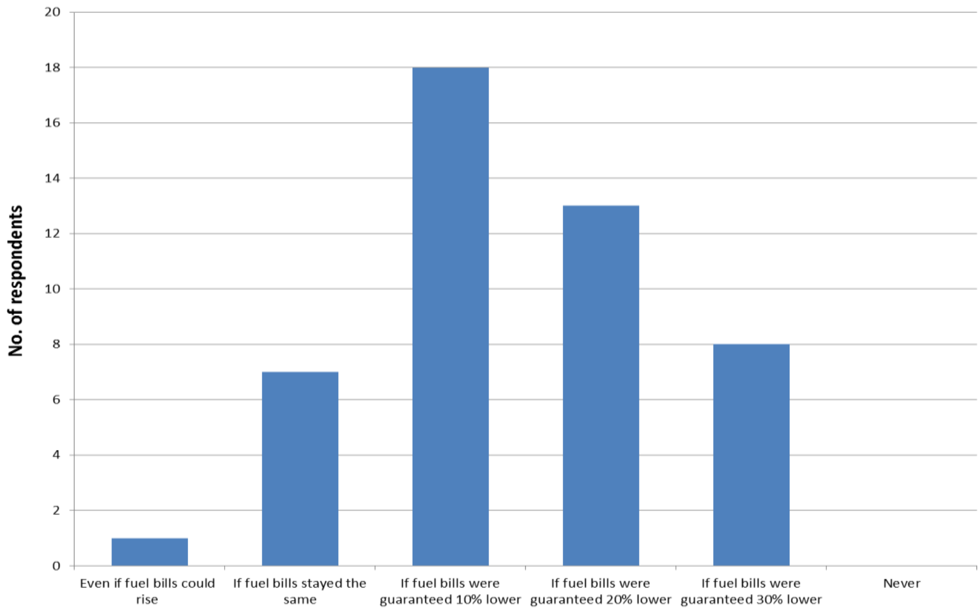

Figure 16 The price at which respondents would switch over to biomass CHP/DHN

As Figure 17 indicates, cost is less important to those strongly in favour of RE. However, costs would appear to be the over-riding factor even for those in favour of RE, and high discounts would sway those who are unsure or even against RE.

[33] as recorded by the researcher.

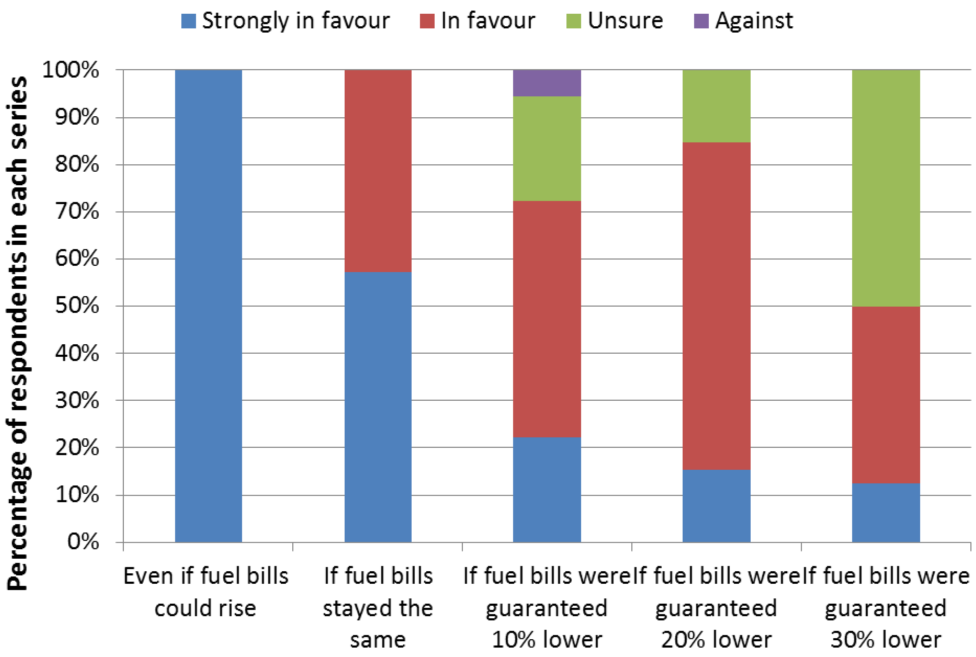

Figure 17 Costs of Biomass CHP and its relationship with general attitudes to RE

Chapter 5. Calculating the annual energy demand to be met by biomass CHP/DHN

5.1 Space heating and hot water demand of "anchor buildings"

5.1.1 Hospital

The hospital accounts department provided the average cost per litre of heating oil, the annual cost of heating oil for the buildings for one accounting year (January – December 2011) and confirmed that this fulfils all hot water requirements, in a phone-call on 27/6/2012.

Table 8 Annual energy requirement for space heating and hot water for the hospital

2011 Cost of heating oil	Price per litre	Litres of heating oil used in 1 year	Equivalent heating oil used in m^3	Caloric Value of heating oil (kWh/m^3) [34]	Annual Energy requirement (kWh)
€102,708	€0.69	148,852	148.852	10,000	1,488,520

5.1.2 Hotel

The researcher was unable to access data regarding heat and hot water use in the hotel. This is not unusual according to the study "Greening Irish Hotels" (Bergin & Hogan 2007) who record the lack of interest and commitment of hotel management to engage in energy management as a major obstacle to achieving carbon reduction targets for the sector. An estimate of the potential energy demand for the hotel has been derived from their study of 100 hotels.

It is assumed this data is applicable in Donegal[35] and that the age of parts of this hotel (established 1845) would mitigate against the hotel being at the lower end of the energy use spectrum. The figure of $606kWh/m^2$, between the average and highest use was adopted.

The floor area of the hotel in the case study is $2{,}175m^2$ based on measurements taken from the ground and from Google Earth (2012). Annual energy use was calculated as 1,318,050kWh.

5.1.3 Swimming Pool

The centre is under construction and due to open in 2013. The specification is: 25m swimming pool, children's pool, ancillary facilities, cryotherapy pool, fitness suite, and changing rooms (FVAC 2012).

[34] BEC 2012
[35] Though only hotels south of Sligo figured in the study.

Despite willingness of the Finn Valley Athletic Centre to provide figures, these are held by a consultancy firm and not available for the purposes of this study. The footprint of the leisure centre was measured as 1,999m^2. Based on the description of the pool size and facilities benchmark figures were used to estimate the annual energy demands. A benchmark figure of 954.5kWh/m^2 was adopted, between typical practice and good practice benchmarks (Carbon Trust, 2006). The annual energy demand for the leisure centre is estimated at 1,908,045kWh.

5.2 Residential demand for space heating and hot water

5.2.1 Use of the Building Energy Rating system (BER) to assess energy demands

The principle means of determining energy demand was use of the BER as defined by Curtin (2009) in relation to the year of construction, see Figure 18.

Use of the BER for this study is based on the same assumptions as the IIEA Greenprint report (Curtin 2009) i.e. all buildings meet minimum building standards.

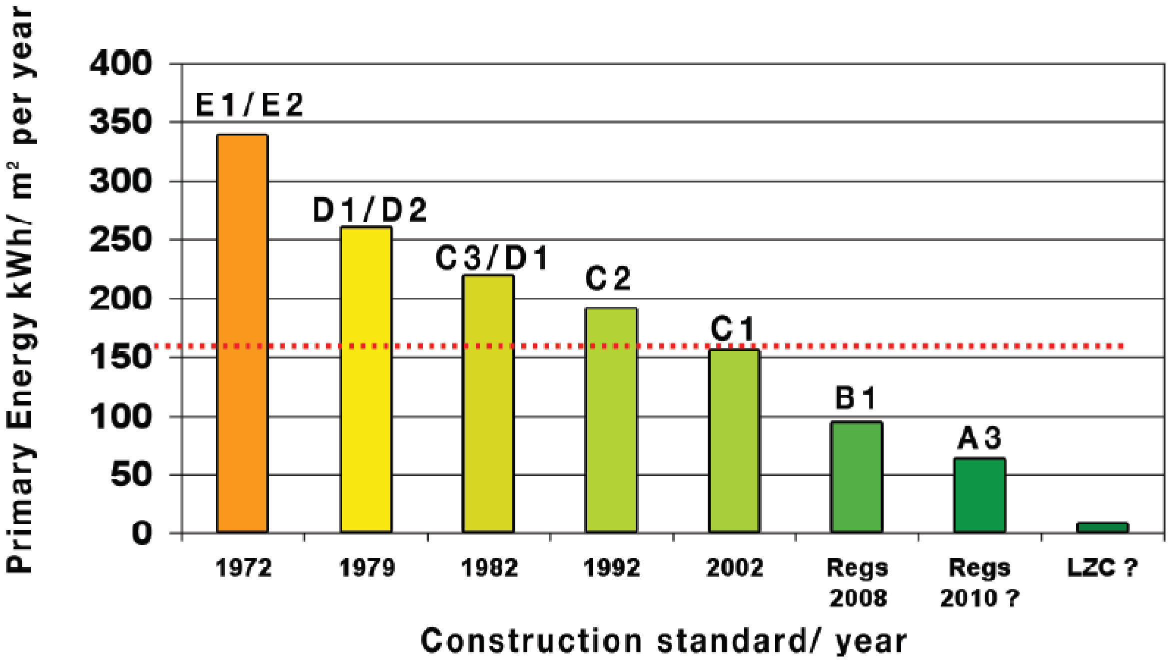

Figure 18 Energy use in relation to BER

(Curtin (2009) pp38 (adapted from O'Rourke, Housing in a Changing Climate Conference, June 2008)

Minimum energy standards as they relate to BER bands for buildings constructed over time are more clearly presented in Table 9 below.

Table 9 Minimum energy standards in relation to the year of construction

Year inclusive	Pre 1972	1972-1978	1979-1981	1982-1991	1992-2001	2002-2007	2008-2009
Rating	F-G	E1-E2	D2	C3-D1	C2	C1	B3-B1
Energy(kWh/ m^2)	380-450+	300-379	261-299	201-260	176-200	151-175	76-150

A proportion of energy in the BER is for lighting and electrical ventilation[36]. The average annual energy consumption for domestic lighting[37] of 9.3 kWh/m^2/yr (SEAI 2008pp 56) is required to adjust for this.

From the questionnaire and a site survey a total of 15 house types A-R were identified, sharing the following characteristics: floor area, year of construction and number of storeys. See Appendix 1.2.

5.2.2 Household Ages, Floor Areas and Energy Efficiency Improvements in the study area

These are all required for the BER to be used to assess energy demand.

Housing ages were established in relation to the bands of time in Table 9 and were determined primarily from responses to the questionnaire survey, except for types Q and R for which historical maps were used.

Floor areas for the different house types were calculated using a 1:10 000 ordnance survey map, and Google Earth measuring tool. Where possible these were checked against typical dimensions for housing types described on the property market.

The percentage of properties[38] who had undertaken three types of energy improvements was taken from the questionnaire survey. Data is presented in Appendix 1.2. The average floor area of properties in the study area is 110m^2.

To assess the impact of some key energy efficiency improvements identified during the survey, the expected energy savings for each measure are considered. An SEAI study (Scheer & Motherway 2011) drawn from a survey of some 1500 houses, provides a suitable set of values for a range of these (see Table 10 below). The houses are classed into three types as follows:

[36] Assumed to be negligible for the purposes of this study
[37] without energy saving light bulbs
[38] For house types Q and R these are estimates, based on results from the rest of the survey

1. 3-4 bedroom detached house of 140m^2;
2. 3 bedroom semi-detached house of 110m^2;
3. 2 bedroom apartment of 50m^2.

Only three of the measures considered in the SEAI study were identified in the Stranorlar study area – roof/attic insulation; cavity wall insulation; new HE boilers and hot water cylinder.

Given the high proportion of terraced and semi-detached properties in the study area (and the average floor area of 110m^2) the values for housing Type 2 are the most appropriate to use, for calculating potential reductions in energy demand from these three measures.

Table 10 Energy savings from various energy efficiency measures as calculated in the SEAI study[39]

	Semi-Detached Savings per measure (kWh)	Savings per measure (kWhm^{-2})
Attic insulation	1,300	11.8
Cavity Wall Insulation	3250	29.5
High Efficiency gas or oil boiler with heating controls and hot water cylinder	7700	70

These figures can now be used to factor in an allowance for energy improvements to homes in the Stranorlar study.

5.2.3 Assessing if the BER standard pattern of occupancy is appropriate

The BER assumes a "standard pattern of occupancy" - a heating season from October to April and a heating day of seven hours (SEAI 2008). Any strong deviation from this pattern should also be accounted for.

Survey results indicated 34% of respondents use their central heating for an extended heating season from September to May, 26% from October – April only, and 36% year round, though the researcher noted several comments such as "but not as much during the good weather" or "only on the odd cold day in the summer".

Regarding weekly patterns of use, 28% of respondents gave mornings and evenings as their normal pattern, 13% weekday mornings and evenings and all day at the weekend, 19% all day every day, and 34% evenings only.

[39] (Scheer & Motherway 2011 Table 2 pp 15)

If this mismatch between heating hours in the survey sample and those assumed for the BER is typical of the whole population, then it would be useful to compare the total heating hours with those on which the BER is based. The calculation was performed for the study area of 347 houses based on the following set of assumptions:

- The heating pattern of the sample is representative;
- "Morning and evening" has the same allocation of heating hours as the BER;
- "All year round" means 90% of the days in a year, to allow for a small proportion of non-heating days.
- "All day every day" is represented by 11 heating hours.
- Daytime heating at weekends adds 8 hours to the heating week (or 1.14 hours per day).

Annual heating hours for the sample were then calculated using the BER standard pattern of occupancy, and secondly with the heating patterns deduced from the questionnaire survey. The results are illustrated in Figure 19.

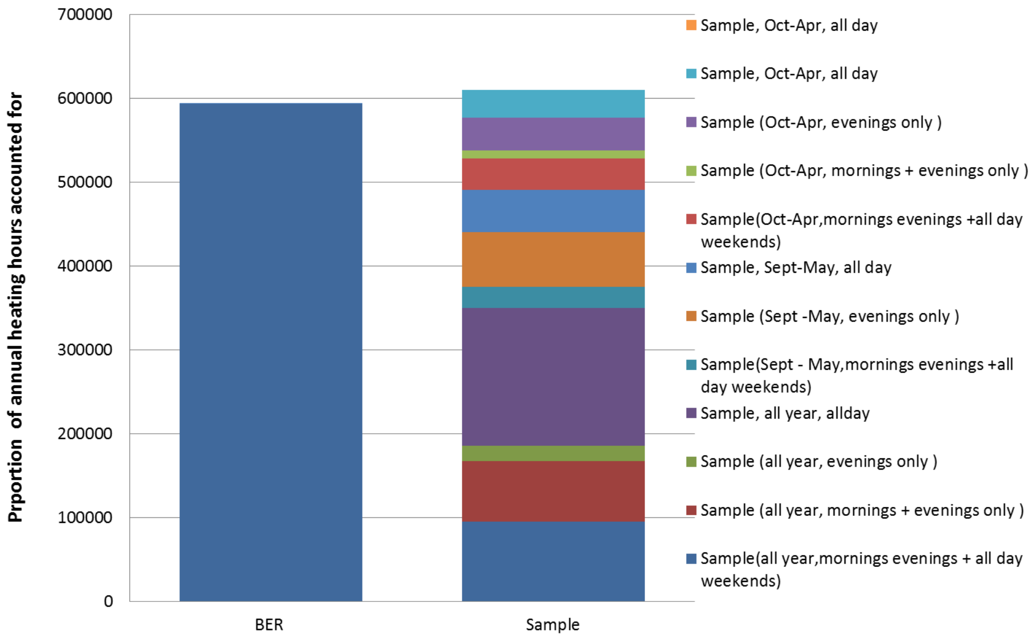

Figure 19 Comparisons of annual heating hours used in the BER with those from the sample survey results

While the survey sample shows a slightly higher annual total than that assumed for the BER, it appears the BER data yields sufficiently robust results for a weighting factor not to be required.

Seasonal differences in the distribution of energy use over a year will be recalibrated using degree days[40]. Differences in these patterns between the BER and the survey results can therefore be ignored for this study's purposes.

5.2.4 Results

Calculations of the overall residential energy demand, estimated using the BER, are adjusted for lighting and energy efficiency improvements, to give an annual figure of 8,426,347kWh. See data in Appendix 1.2

This is an average of 24,283 kWh per house, somewhat higher than the national average of 19,713 kWh for fossil fuel use (O'Leary et al 2008).

Possible reasons for this are:

- energy efficiency measures undertaken are under-recorded – people are unaware of improvements carried out;
- use of the higher end of the BER rating to account for lack of enforcement of building regulations;
- The SEAI figure is from 2006, and does not include electricity for heating hot water;

Residential energy use for space heating for the 347 houses in the study area was calculated as 8,426,347kWh per year with 1,041,000kWh per year of this allocated to energy for hot water. Estimates for hot water use vary. In this instance the figure of 3,000kWh per house per year (Boait et al 2012) was used as the basis for demand.

5.3 Distance over which to lay the DHN

A simple layout of a DHN system to supply the three anchor buildings and the 347 homes in the study area was designed as illustrated in Figure 20.

[40] See section 6.1

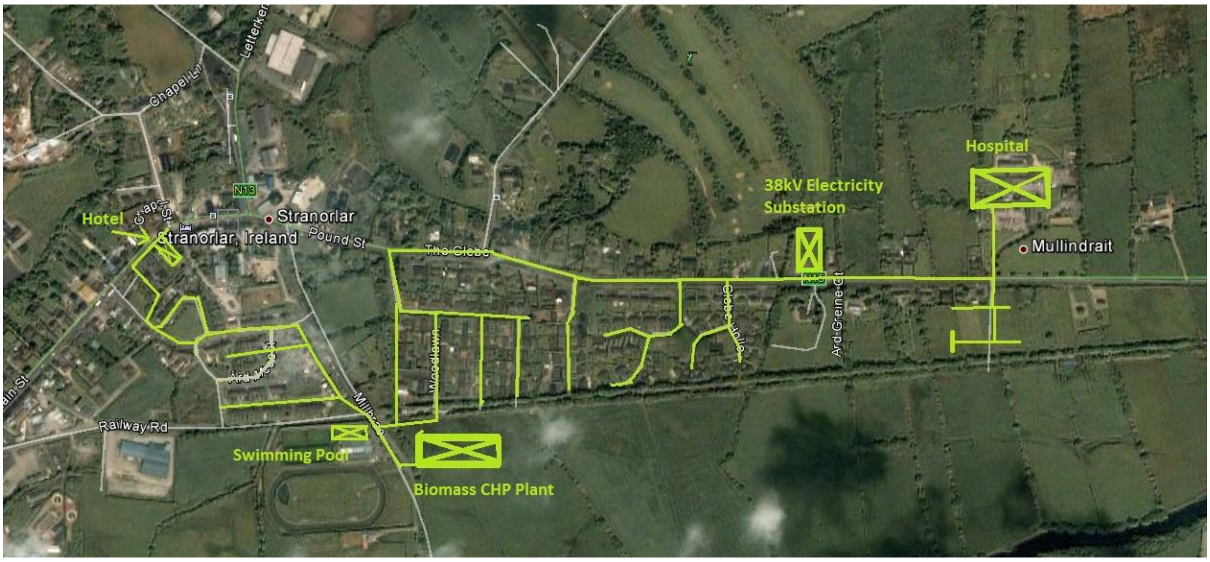

Figure 20 Satellite Map of Stranorlar showing a simplified DHN layout, key sites and a proposed location for the biomass CHP plant (Google Earth 2012, GeoEye 2012)

Measurements were then taken from a 1:10 000 scale ordnance survey map and from Google Earth. Distances to connect each house type were also measured and averaged. The figures obtained are presented in Appendix 1.2a and summarised in Table 11.

Table 11 Overall lengths of DHN pipeline required

Main pipe length, (m)	Connections to houses (m)	Total length of pipe required at 100% connected	Average length of connection per house (m)
3,745	3,628	7,373	10.45

5.4 Evidence of a potential local biomass supply chain

Stephen Meyen, the local Teagasc forestry development manager,in a meeting on 14/03/12 confirmed Stranorlar is located within the heartland of Donegal private forestry and has access to a supply of pulpwood within a 30km radius at least to 2030.

In 2008, private woodland owners formed Donegal Woodland Owners Group, a county-wide producer group supported by Teagasc and Donegal County Council.

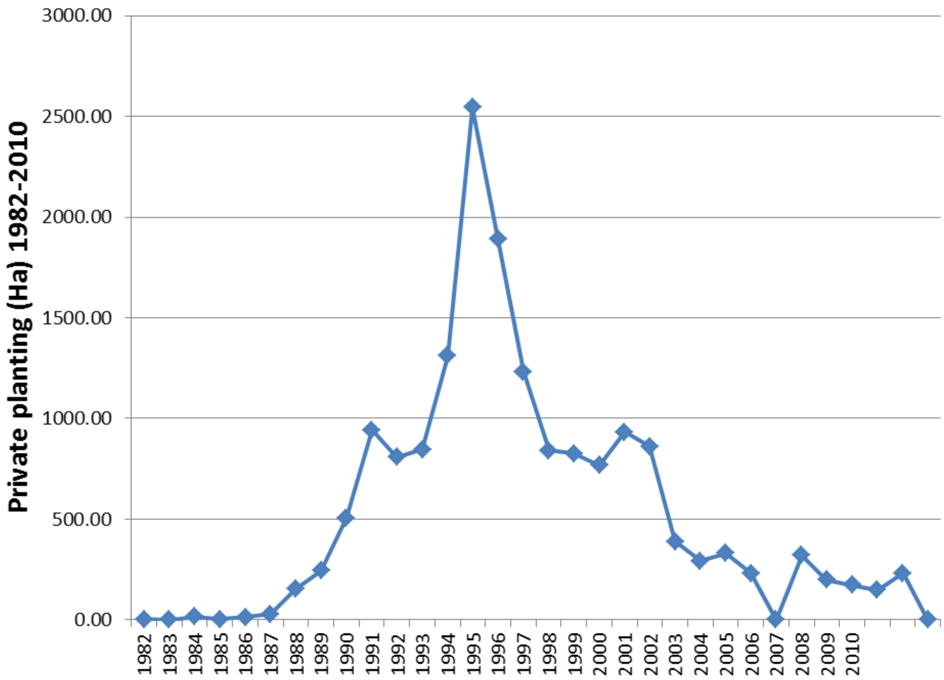

Figure 21 Hectares of Donegal forestry planted 1982 – present, adapted from statistics from Teagasc (2012)

Figure 21 reveals that thinnings will guarantee a supply of pulpwood over the lifetime of a biomass CHP/DHN project up to around 2035 (see 2.3.2) but there is a strong likelihood of a future shortfall if planting does not increase in the near future.

5.5 Numbers of potential customers

The potential uptake of a biomass CHP/DHN scheme by residential customers was drawn from results of the questionnaire survey.

Respondents were asked the price at which they would be inclined to join up to the scheme given a sliding scale of energy costs in comparison with their current costs, the results of which were seen in Figure 16 and which equate to percentages in Table 12 below.

Table 12 Numbers and cumulative percentage of potential customers given different pricing structures.

	Even if fuel bills could rise	If fuel bills stayed the same	Fuel bills guaranteed at least 10% lower	Fuel bills guaranteed at least 20% lower	Fuel bills guaranteed at least 30% lower	Never
No. of respondents	1	7	18	13	8	0
Potential no. of customers in the study area	8	52	133	95	59	0
Cumulative %age of potential customers	2%	17%	55%	82%	100%	0

These percentages were used to develop the 3 scenarios used in Section 7.1.

5.6 Commercially available, small-scale CHP plant

Approaches were made to those companies listed in Table 2 for plant specifications and associated costs. Information from case studies was also requested. The only plant for which detailed information was forthcoming was from BEL, (BEL, n.d., Flaxington, 2007, Scott, 2011) who quote ST£1.5-2million equivalent to €3600-4800 per kW_e for their $500kW_e$ plant (BEL, n.d.)

Technical details of plant sized at $125kW_e$ and $250kW_e$ from Cleanstgas/KWB that is poised to enter the market during 2012/13 was also purchased (Timmerer et al., 2011) and anticipated costs for this were obtained in an e-mail on June 18 2012 from an unnamed contact in the industry of €4,700 per kW_e, a $500kW_e$ plant would therefore cost €2,350,000.

The key information provided by BEL in addition to costs were the efficiency ratios associated with their plant, as illustrated below in Figure 22.

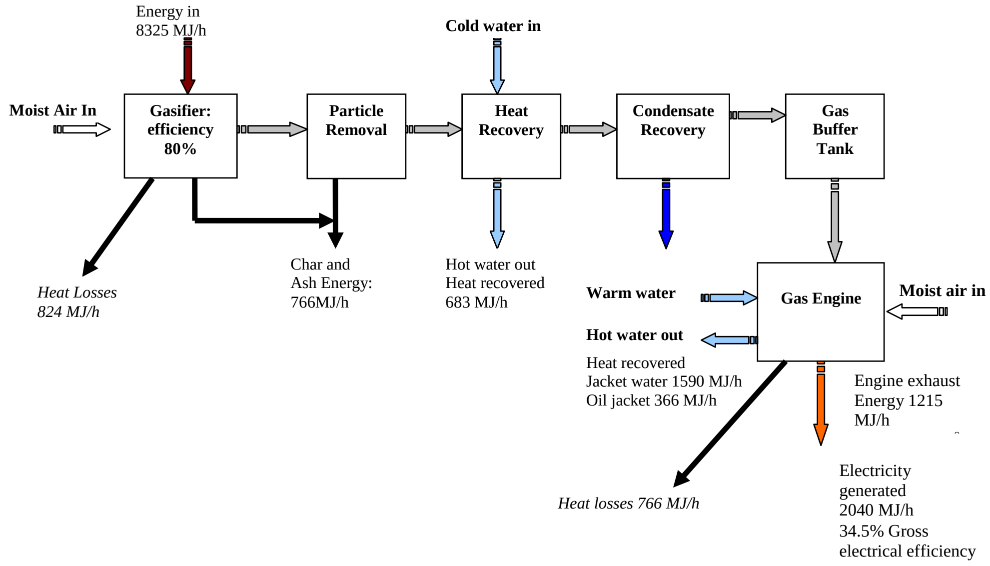

Figure 22 Heat Mass Balance for 500kW$_e$ system (BEL n.d.)

Efficiency is highly dependent on the moisture content of the woodchip, with a gross electrical output of 597kW$_e$ for wood at 15% moisture content or 630kW$_e$ at 10% moisture content. At 15% moisture,

Net thermal efficiency = 46.3% Net electrical efficiency = 24.5%

Overall efficiency = 70.8%

Net electrical output from the 500kW$_e$ engine with wood at 15% moisture is 424kW$_e$ (85%).

These efficiencies are similar to those given for the Cleanstgas/KWB plant where overall efficiencies of >75% are thought achievable (electrical efficiencies ≥26% and thermal efficiencies ≥50%) (Timmerer et al. 2011).

The wood-fuel specification was also supplied, this is very precise and demands close monitoring of the drying, chipping and screening processes, with levels of moisture content carefully measured for 30 samples per 250kg fuel prior to use in the gasifier (Scott 2011). For this reason, it is assumed that the drying and chipping processes will all be carried out on site to ensure compliance with the quality of woodchip required.

5.7 Costs and Income

Table 13 Capital costs associated with biomass CHP/DHN

Capital Item	€	Unit	Source (see below)
Biomass CHP Plant	4,300	per kW_e	a
Grid Connection	137,572	per connection	b
Secondary plant – heat only biomass boiler	672	per kW_{th} (installed)	c
Interface unit	1,560	per unit	d
250kW Substation	9,600	Per unit	e
DHN Pipe and pipe-laying including joints (twin pipe Aluflex)	500	per linear metre	f
Trenching/Civils (road)	85	per linear metre	g
Buildings	150,000	150m^3 fuel storage, auger, wood chipper and plant room	h

a. Middle range price see 5.6 above.

b. Table 14 below shows the cost of connecting plant located 0.75km from the 38KV ESB substation in Stranorlar, following from a worked example (SEI 2008) with costs obtained from the ESB (2011).

Table 14 Connection costs for a generator <1MW$_e$

Connection Asset	Cost (€)
MV Cubicle in 38kV substation	56,300
0.75km dedicated MV overhead line	38,002
MV meter <10MVA	28,150
ESB Communication Equipment <2MW	15,120
Total	**137,572**

c. A quote of €672/kW_{th} (installed) was obtained in a phonecall from Eddie Meenan on 9th August 2012.

d.e & f. These costs were provided by Dave Kragh, in a phonecall and via e-mail on 27th July 2012. Substations may be required for anchor buildings, in which case it is assumed that costs will be borne by the customer.

g. Approximate costs for “civils” - digging trenches and restoring road surfaces were obtained from Conal McCauley by phone call and e-mail June 27th and June 29th 2012 respectively.

h. A nominal cost of €150,000 for the buildings and equipment required to store and chip the wood was obtained from a worked example by Luker (2007) for a 150m^3 fuel storage, auger, wood chipper and plant room to supply a 1.5MW$_{th}$ boiler.

Table 15 Running Costs associated with biomass CHP/DHN

Running Costs	€	Unit	Source
Wood (roadside price)	0.0371	per kWh	i
Transport	0.00198	per kWh	j
Operation and Maintenance	10%	of capital cost of CHP plant	k

i. A price of €27/m^3 for pulpwood (roadside price) (Teagasc 2012a) is used to obtain this figure, based on calculations presented in Appendix C.

j. Within a 30km radius transport costs €7 per tonne (maximum permissible cargo of 25 tonne)as estimated from McCools Sawmill in a phonecall on 17th July 2012.This is consistent with the WDC et al. figure for haulage costs of €8.85/tonne within a 20-40km radius (pp 28 2011).

k. 10% of capital cost of CHP plant including waste disposal is a nominal figure. This will depend on manufacturer’s specifications for the actual plant.

The heat income in Table 16 is calculated based on current home heating oil prices, see Figure 23 below.

Table 16 Income associated with biomass CHP/DHN

Source of Income	€/kWh
REFIT tariff	0.14
Heat income at current oil price	0.1207
Heat income at 10% discount	0.1086
Heat income at 20% discount	0.0966
Heat income at 30% discount	0.0839

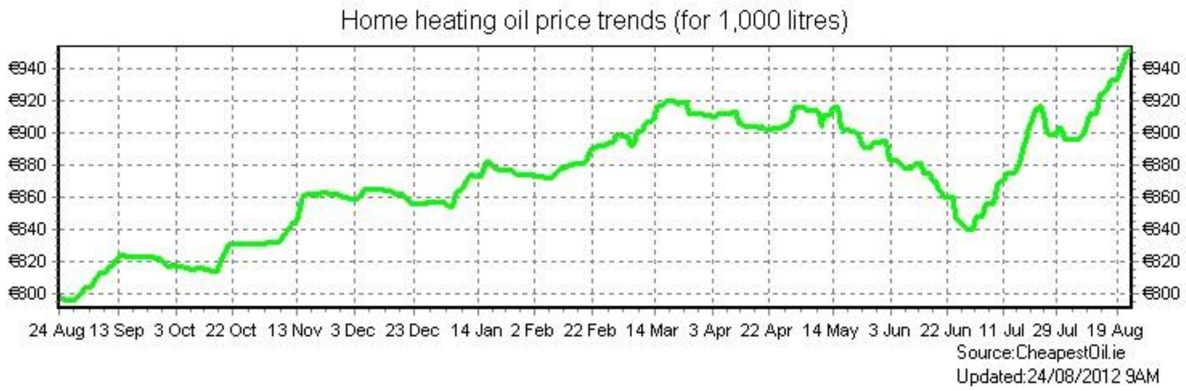

Figure 23 The past year's data (Cheapest Oil Ltd., 2012).

An average cost of €860 per 1000 litre is taken. Then if household oil boilers are 70% efficient (SEAI 2011) and the heat value of kerosene is 10.18kWh per litre (SEAI 2011), heat output is 7.126kWh per litre.

At current prices, householders are paying €0.86/7.126kWh or 12.07c/kWh for the energy they use, including a carbon tax of €0.00277 per kWh (SEAI 2011).

5.8 Summary of Assumptions

- Data collected on space heating and hot water demand is sufficiently accurate to reflect patterns of actual demand;
- While not optimised, the DHN layout is sufficiently accurate to reflect the costs involved in its construction;
- All estimates and quotations are accepted in good faith;
- An exchange rate of ST£1.00 =€1.20 is applied throughout;
- Prices are Value Added Tax (VAT) exclusive.

5.9 A discussion on Validity and Reliability of the results[41]

The most reliable energy use data came from the hospital, and together with degree day data and benchmarks on how energy is used in hospitals will give an acceptable estimate of its energy demands. The use of benchmark figures for the hotel and swimming pool can only provide an approximation of the annual energy use of these buildings. The lack of good quality, reliable data on energy use in buildings is a major problem and is a key subject in the discussion that follows in Chapter 8. Nevertheless, benchmark figures are often used in feasibility studies (Action Energy 2004) and are deemed useful in the context of preliminary assessment.

[41] N.B. For the questionnaire survey results, see section 4.3.

Ages and floor areas of houses in the study area are sufficiently accurate for the purposes of this study, as is the linear measurement of DHN. However, margins of error are wider than would be desirable in a full feasibility study and DHN layout in particular would need to be designed and priced by a qualified engineer.

While a biomass supply chain is not currently active, there is confidence at local level to assert that enough forestry of the right age currently exists within a 30km radius of Stranorlar to provide the plant with fuel for at least the next 20 years. Predictions beyond this point are more uncertain.

It was more difficult than expected to obtain detailed performance data on small scale biomass gasification technologies, though other studies highlight similar uncertainties associated with obtaining information from manufacturers and suppliers (Dong, Liu & Riffat 2009, Barbier 2010). Because the technologies are so new and have yet to be trialled and tested over the 20 year period suggested as a reasonable lifetime for plant, some caution is required in assuming that this will indeed be the case, as, depending on the payback period, this could be a strong limiting factor in delivering the project.

Chapter 6. Establishing monthly patterns of energy demand

6.1 Degree Days

The data gathered and presented in Chapter 5 requires further analysis in order to establish monthly patterns of energy demand for space heating and hot water in the study area.

Degree days can be used to allocate monthly patterns of use of energy for space heating. All those used in this study were sourced from www.degreedays.net (Bizeesoftware 2012). Data from weather station 03904: Castlederg[42], NIR, GB (7.58W, 54.71N) in Northern Ireland, close to Stranorlar, was used (see Figure 5 Location of the study area, (Google).

Unless stated otherwise, the latest five-year average of degree day data was used, to smooth the effects of two exceptionally severe winters in 2009 and 2010 when Castlederg recorded the coldest temperature on record in Northern Ireland, -18.7°C (BBC 2011).

Base temperatures were selected depending on relevant indoor temperatures of the different buildings. Base temperatures are generally selected at 3°C lower than the required indoor temperature to allow for internal gains.

Energy for hot water use is always assumed as independent of weather and is therefore removed from the annual total prior to degree day analysis and distributed evenly over the twelve month period.

Degree day analysis performed on the annual totals calculated in Chapter 5 for each of the anchor buildings and for the residential sector follows. In each case an annual energy demand profile is constructed.

6.2 Patterns of Energy Demand, Anchor Buildings

6.2.1 The Hospital

The ratio of hot water use in hospitals to space heating can be estimated using a generic profile of energy use in Irish hospitals, illustrated in Figure 24.

[42] Data from this station is available since 2004 and is 7% estimated (BizEEsoftware 2012)

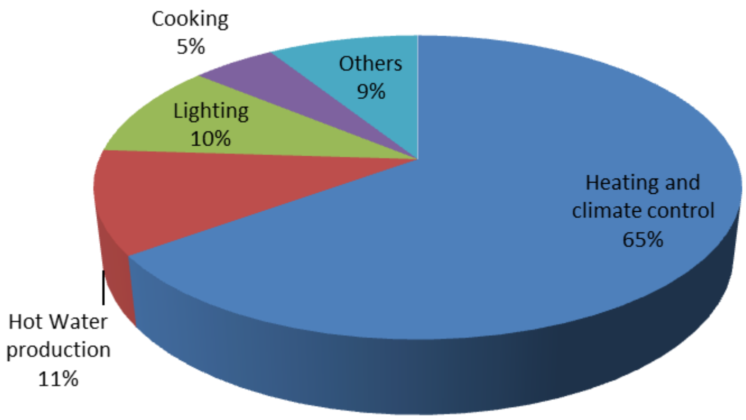

Figure 24 Energy use in hospitals (adapted from SEI (n.d. pp2.))

Annual energy use of 1,488,520kWh (see 5.1.1) for the hospital in the study area includes *only* hot water and heating[43] so the proportion used for hot water is 11:65 or 14.5% of this. This figure, 215,835kWh is first removed so that degree day analysis can be performed for the space heating.

Because heating oil use was obtained specifically for 2011, degree days from 2011 were used with a base temperature of 18°C, since hospitals are generally maintained at a temperature of at least 21°C (CADDET 1997).

The energy demand profile for the hospital is illustrated in Figure 25 below, from data in Appendix 1.3.

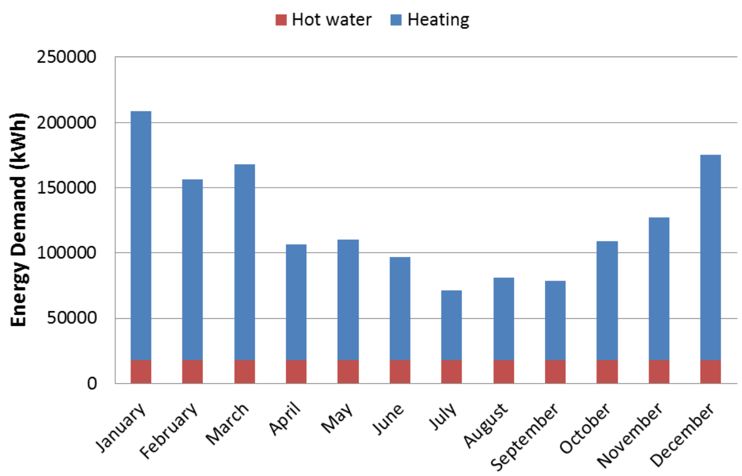

Figure 25 Energy demand profile for the hospital

[43] Assuming there is no climate control

6.2.2 The Hotel

Analysis for this building is more tentative than for others in this study. In section 5.1.2 a figure of 1,318,050kWh per year was obtained for the annual energy requirement of the hotel, including catering. Allocation of the energy used for heating and hot water and for the small leisure centre attached to the hotel is based on industry benchmarks for natural gas use see Figure 26.

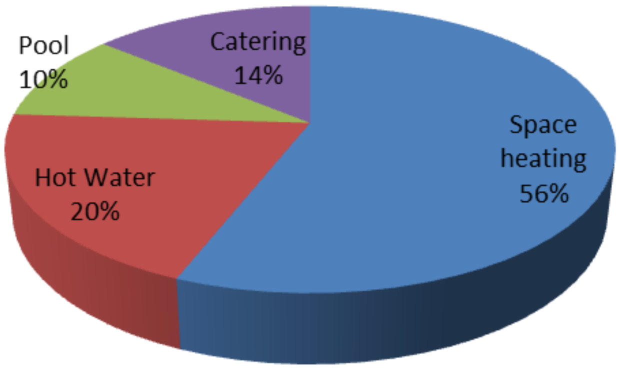

Figure 26 Estimate of energy use for hotels, Powertherm Solutions (2012)

All the heat and hot water needs of the Stranorlar hotel are met by oil, and catering by LPG, so removal of catering from the equation is needed to adjust the percentages in Figure 26 from gas to oil, used for hot water, space heating and the pool. The typical split in fossil fuel and electricity use in hotels is given as 3:1[44], this also informs the allocation of energy use given in Table 17.

Table 17 Allocation of energy demand for the hotel

		Fuel type		Fossil fuel allocation		Oil allocation		
Units	**Overall Energy**	**Electricity**	**Fossil fuels**	**Gas (catering)**	**Oil**	**Space heating**	**Hot Water**	**Pool**
kWh/m^2	606	202	404	57	347	226	81	40
kWh per year	1,318,050	439,350	878,700	123,018	755,682	492,072	175,740	87,870

The value of 347 kWhm^{-2}/year (for oil use) compares well with the value of 350kWhm^{-2}/year for typical practice in a small hotel with pool (CIBSE 2004).

Degree days are used to distribute the energy used for space heating through the year in Figure from data in Appendix 1.4. Catering use is excluded. The energy used for the pool is also assumed to be degree day dependent, but with a higher base temperature of 26°C, to

44 360kWh/m^2 (fossil fuels) to 120kWh/m^2 (electricity) (CIBSE 2004)

maintain pool temperature of 29°C as recommended by the Carbon Trust (2005). A base temperature of 15.5°C is adopted for the rest of the hotel.

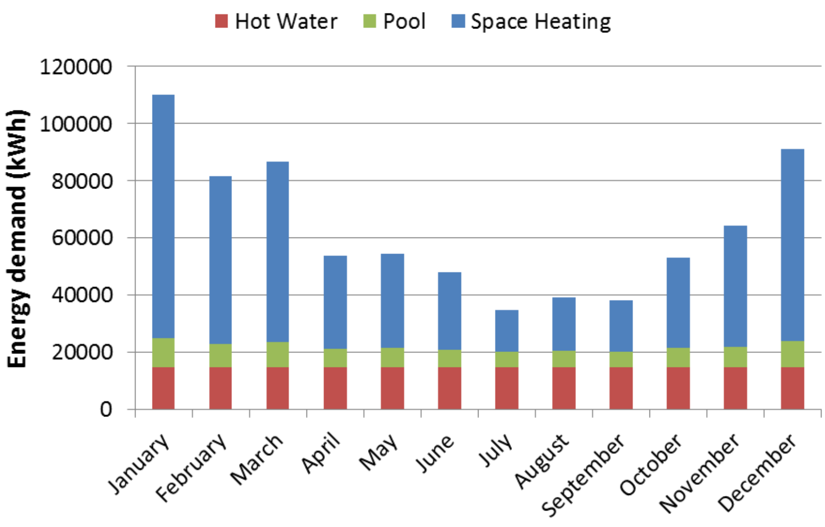

Figure 27 Energy demand profile for the hotel

6.2.3 The Swimming Pool

All the energy used in the swimming pool is taken to be degree day dependent and a base temperature of 26°C is used for the analysis to maintain pool temperature at 29°C. The profile is illustrated below, from data in Appendix 1.5.

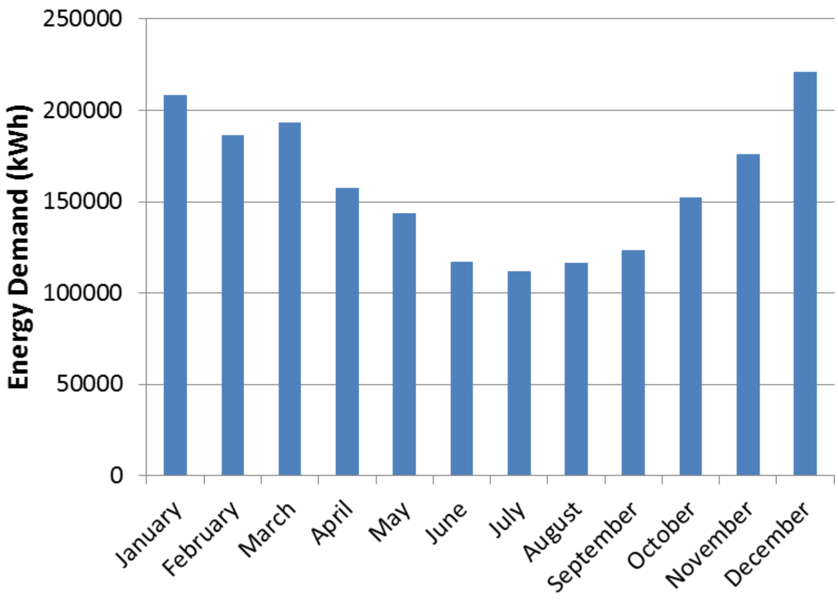

Figure 28 Energy demand profile for the swimming pool

6.3 Residential Energy Use

Annual energy use in the 347 houses in the study area was calculated in section 5.2.4 as 8,426,347kWh per year of which 1,041,000kWh is allocated to hot water.

A standard residential base temperature of 15.5°C was used for degree days and the resulting profile is illustrated in Figure 29 from data in Appendix 1.6.

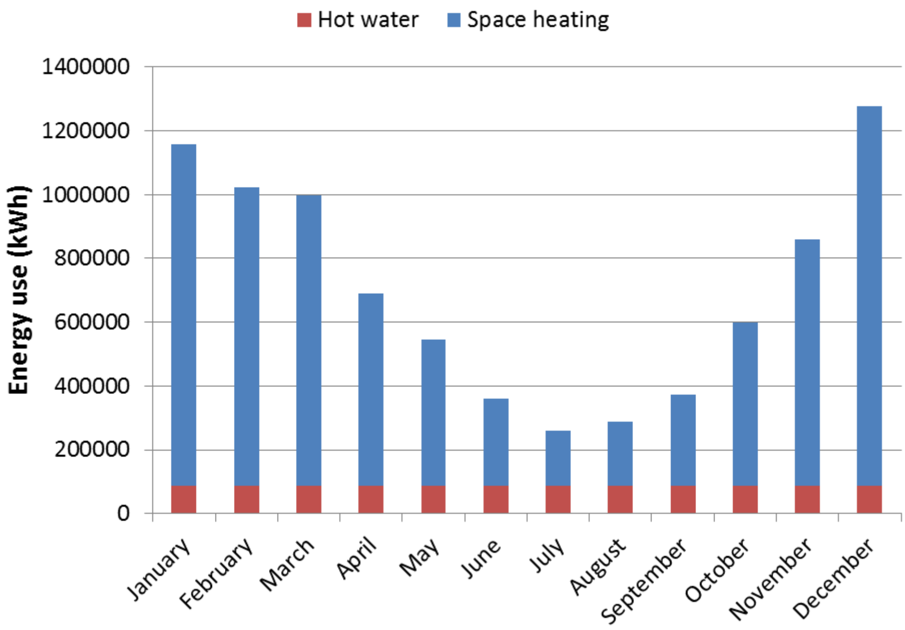

Figure 29 Residential Energy demand profile for all 347 houses in the study area

6.4 Summary of Energy demand

The energy demands for all the building types are listed in Table 18.

Table 18 Summary of Energy Demand

Building Type	Space heating	Hot Water	Pool	Total Annual Energy demand (kWh)
Hospital	1,271,020	217,500	---	1,488,520
Hotel	492,072	175,740	87,870	755,682
Swimming Pool	---	---	1,908,000	1,908,000
Residential	7,385,367	1,041,000	---	8,426,347
All Buildings	**9,148,459**	**1,434,240**	**1,995,870**	**12,578,569**

Chapter 7. Investment Appraisal

7.1 Energy Demand Scenarios

Three scenarios for demand for the heat energy provided by a biomass CHP plant with DHN are considered for the purposes of investment appraisal based on the results of the questionnaire from Table 12.

This suggested that 82% of residential customers would join the scheme if offered a 20% discount on fuel bills and 55% for a 10% discount. Only a 30% discount might attract 100% of customers and "back-of-the-envelope" calculations quickly show this is not a feasible option. Instead, an optimised scenario of 100% uptake, no discount, was employed for purposes of comparison.

Participation of two of the anchor buildings, the swimming pool and hospital, is considered as pivotal to the success of the scheme, and are included in every scenario.

- **Scenario 1 (optimised)** -Three anchor buildings plus 100% residential uptake, no discount ;
- **Scenario 2** Three anchor buildings plus 82% residential uptake at 20% discount on current heating oil prices;
- **Scenario 3** Two anchor buildings (no hotel) plus 55% residential uptake at 10% discount on current prices.

7.2 How the total energy requirements are distributed for each scenario

Distribution of the total energy requirements over the year for each scenario was calculated from summing the total energy established for each category of buildings in Chapter 6 and resulting frequencies of distribution are illustrated in Figure 30 to Figure 32 below. Data used to construct these figures is presented in Appendix 1.7.

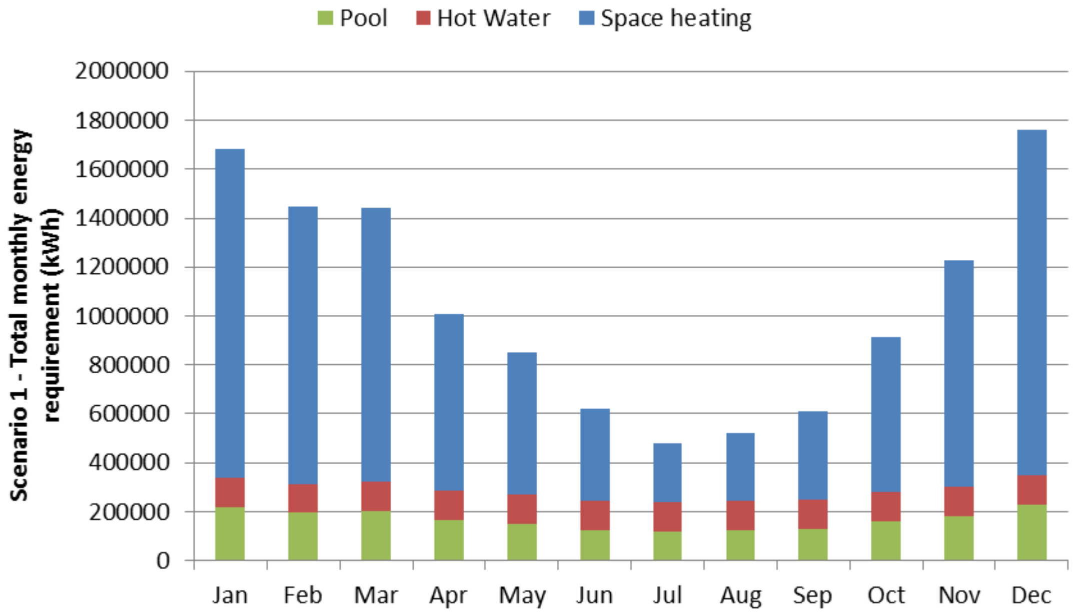

Figure 30 Monthly energy demand Scenario 1

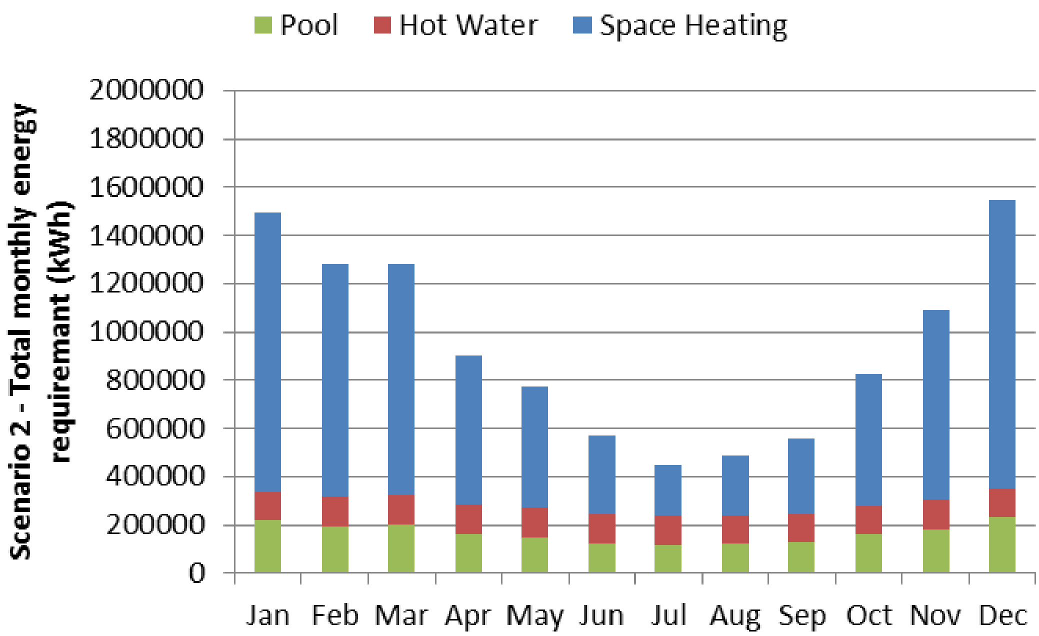

Figure 31 Monthly energy demand, Scenario 2

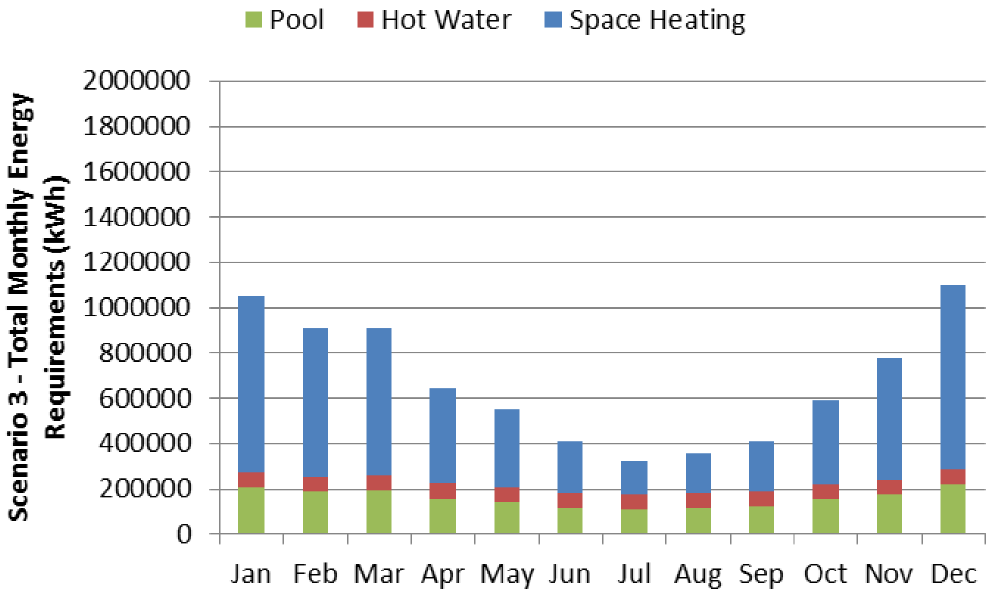

Figure 32 Monthly energy demand, Scenario 3

These figures illustrate peak monthly energy demand to be over 1.5 times higher for Scenario 1 than for Scenario 3. Demand for hot water and heating for swimming pools, as expected, shows less variation over the course of the year than space heating demand, which peaks in December and is at its lowest during July.

Peak monthly demand ranges from a maximum of 1,763,337kWh (December figure, Scenario 1) to 1,098,150kWh (December, Scenario 3). This, however, does not equate to the peak load, which is the power required to deliver the maximum thermal energy demand (usually occurring at peak demand time of the coldest day of the year). Peak loads are required to establish the correct size of plant to meet *all* the heat energy demands made upon it, and are calculated in the next section.

7.2.1 Peak and Base Loads

Monthly energy demand profiles mask the fluctuating base and peak loads, which occur on a daily basis with the base load usually occurring at night. Since figures for the daily distribution of heat are not available for this study area, an approximation is required.

To calculate the base load (Q_{base}), the hour in the year at which the demand is lowest (assumed as overnight in July) is equal to the distribution losses from the DHN plus the July heat demand for the swimming pool, evenly spread, and a nominal 10% of the total of heat and hot water.

$$\mathrm{Qbase} = \frac{\mathrm{DL} + \mathrm{Julypool} + 0.1\mathrm{Julyspaceheating} + 0.1\mathrm{Julyhotwater}}{720} \quad \textbf{Equation 1}$$

To calculate the daily peak load, occurring in January, the following assumptions are made, based on information gleaned from the BER in combination with results from the questionnaire survey: 70% of the total space heating required occurs over a daily 7 hour period, 80% hot water use is spread over 17 hours and DHN distribution losses and swimming pool use is evenly spread 100% over 24 hours.

$$\text{Qpeak} = \frac{\text{DL+ Decemberpool}}{720} + \frac{\text{0.7Decemberspaceheating}}{210} + \frac{\text{0.8Decemberhotwater}}{510} \quad \text{Equation 2}$$

Monthly heat requirements for each scenario are taken from information gathered on the total heat demand of the various building types. For peak load, the December total is used, while for the base load, it is July. Daily loads are assumed constant across the month.

Table 19 Peak and Base loads calculated for the 3 Scenarios

Scenario	Peak load (kW_{th}) / Peak load as a %age of the daily load	Base Load (kW_{th}) / Base load as a %age of the daily load	December monthly / daily total heat demand (kWh_{th})	July monthly / daily total heat demand (kWh_{th})
1 – 100% residential uptake, 3 anchor buildings	5,305 / 9.0%	749 /4.7%	1,763,337 / 58,778	477,160 / 15,905
2 – 82% residential uptake, 3 anchor buildings	4,560 / 8.6%	677 / 4.2%	1,590,392 / 53,013	487,106 / 16,236
3 – 55% residential uptake, 2 anchor buildings	3,180 / 8.3%	518 / 4.1%	1,145,494 / 38,183	372,881 / 12,429

7.2.2 A comparison of base and peak loads calculated for this study with those arising from half hourly data

The validity of this methodology for calculating peak and base loads, designed specifically for the study sample, was checked against profiles constructed for peak and base residential loads where half-hourly daily demand data is available.

A generic profile for daily heating demand, based on data from a field trial of domestic micro CHP by the UK Carbon Trust, and used as a demand model by the SEAI Energy Forecasts Report (Clancy & Scheer, 2011 pp66) is illustrated in Figure 33.

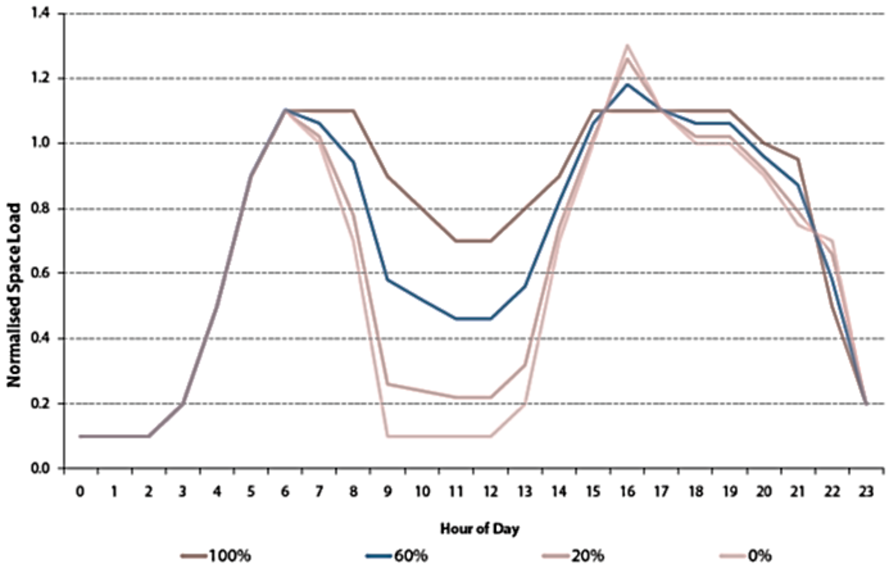

Figure 33 Generic demand profiles for residential heat energy demand as constructed by the SEAI in Energy Forecasts for Ireland, showing (SEAI 2010 pp66)

Tabulated figures for the 20% profile (representing weekday use) in Figure 1Figure 33 are presented in Appendix 1.8.

Peak demand in this generic heat demand scenario corresponds to 7.88% of the daily demand, slightly lower than that calculated by the methodology used for this study, but the difference is small, and we already know that energy use in Ireland is higher than in the UK.

Base load corresponds to just 0.62% of daily demand, somewhat lower than the 4.1 – 4.7 % calculated in Table 19 above, but this difference is easily accounted for by the additional base load created by the anchor buildings in this study.

The peak and base loads calculated in Table 19 can therefore now be used with some confidence to size the CHP plant, to meet all the potential energy demands of the buildings in the study area.

7.2.3 Calculations for sizing of CHP plant

When sizing CHP, unless there is a local use for the electricity, it is usual to size plant to the heating base load or slightly above to avoid unnecessary dumping of heat. Sizing to the peak load is usually only considered when there is a localised demand for all the electricity generated (Carbon Trust 2004). While all the electricity generated here can be exported to the grid, there are environmental problems[45] associated with generating excessive heat, and the overall efficiency of the plant's output is compromised (Action Energy 2004). Plant sized

[45] Such as heat dumping, additional particulate emissions and waste products

to peak load is therefore considered only for purposes of assessing its economic viability compared with the smaller plant.

Because a use exists for some excess heat, i.e. for drying the wood from 30% to 15% moisture content, performance of plant sized above the base load can also be considered.

Calculations involved in determining the amounts of heat required for the drying process are shown in Appendix 1.9. Energy to dry 1 tonne of wood from 30% moisture content to 15% was found to be 118.28kWh, equal to 3.35% of the overall energy delivered by the wood.

Each scenario was assessed for theoretical plant sized to its peak load (5,305kW_{th}, 4,560kW_{th}, 3,180 kW_{th}) and to the corresponding base loads (749 kW_{th} 677 kW_{th} 518 kW_{th}).

Intermediate sizes of plant from 500kW_e to 1MW_e were also selected for comparison. It has already been ascertained that there is a limited choice of commercially available gasification plant at scales below 1MW_e. All the calculations (presented in Appendix 1.10) are therefore based on the specifications available for plant sizes of 125kW_e , 250kW_e and 500kW_e, with efficiency ratios from BEL as discussed in 2.2.2. For larger scale plant, in practice, these efficiency ratios may be slightly different.

Figure 34 below illustrates the difference between the heat produced by the different sizes of plant considered, and demand for that heat. While these are overall annual figures, they are useful guides to choosing the size of plant that most closely matches the overall heat demand.

Logstor Calculator was used to calculate distribution heat losses given pipe lengths for the 3 different uptake scenarios as seen in Appendix D.

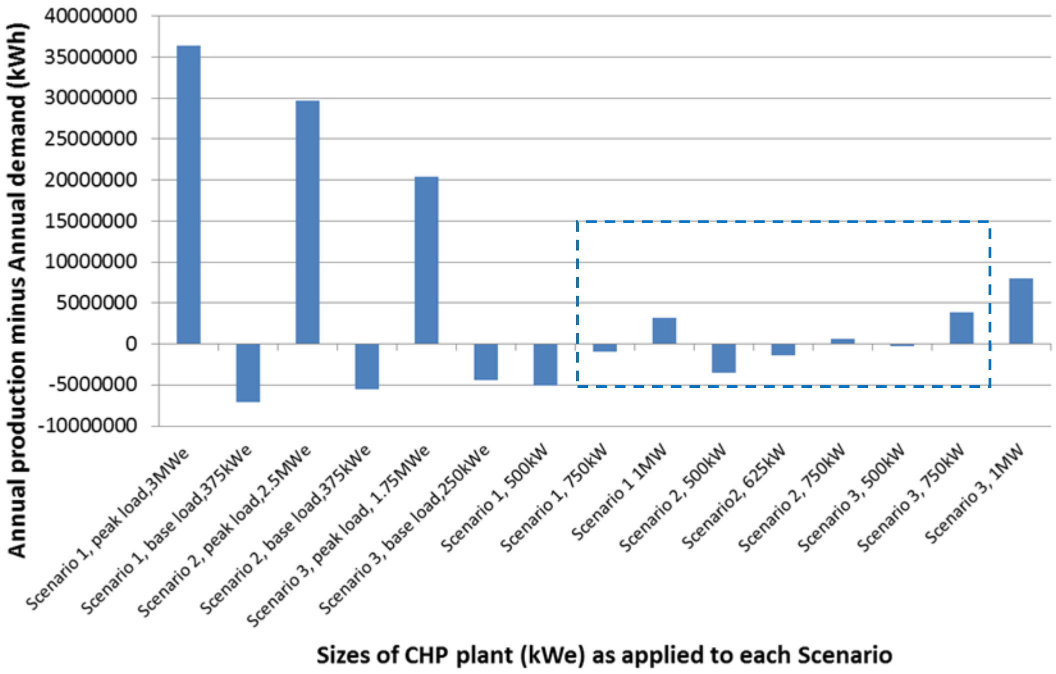

Figure 34 Matching annual output of different scenarios and sizes of CHP plant with annual demand

From Figure 34 it is apparent that sizing to the base load requires a sizeable proportion of annual heat demand to be met from an additional source, while sizing to the peak load involves excessive dumping of the surplus heat generated.

While the *actual* heat demand for each scenario to be met by the CHP plant will depend on *daily* demand/load profiles, the seven demand/load profiles i.e. combinations of plant with scenario, that most closely match the annual heat demand, are identified by the dashed outline in Figure 34.

In order to discover which of these seven profiles, if any, are economically viable, a basic profit and loss account is required, from which a payback period can be derived.

7.2.4 Capital Costs, Overheads and Income

Table 13 - Table 16 in section 5.7 presented the unit capital costs, overheads (running costs) and income associated with biomass CHP/DHN.

These figures were used to calculate gross and net return on capital and simple payback periods for each of the 7 demand/load profiles identified.

It is already known from the peak load tables that a backup boiler will be required to meet the peak load demand. Costs and returns associated with this are therefore included. A biomass heat-only boiler is chosen as it represents an opportunity to capitalise on the equipment, transport and storage facilities already involved. It also ensures that the entire project is classed as an RE project. A boiler that can operate at low outputs as well as maximum output is required. Peak load requirement for the biomass boiler is calculated from the peak load requirement minus the maximum CHP thermal output, and the boiler is sized accordingly (see Appendix 1.11). Some possible moderation of the peak load is assumed, given the number of homes identified in the survey who have secondary heating systems, along with the option to reduce the feed into the swimming pool during peak load times, thereby reducing peak demand.

Table 20 below shows four undiscounted measures of financial returns for each of the 7 heat demand/load profiles. They are:

Gross Return on Capital, GR = $\sum \frac{Annual\ Income\ over\ the\ project\ lifetime}{Capital\ Costs}$

Net Return on Capital NR = $\sum \frac{Annual\ Income\ over\ the\ project\ lifetime - Capital\ Cost}{Capital\ Costs}$

Gross Annual Average Rate of Return = $\frac{Gross\ Return\ on\ Capital}{Project\ Lifetime}$

Net Annual Average Rate of Return = $\frac{Net\ Return\ on\ Capital}{Project\ Lifetime}$

Table 20 Financial returns for each of the 7 heat demand/load profiles as a percentage of costs.

Profile, including secondary plant	Gross Return on Capital	Net Return on Capital	Gross Annual Average Rate of Return	Net Annual Average Rate of Return
Scenario 1, 750kW	205%	105%	10%	5%
Scenario 1 1MW	254%	154%	13%	8%
Scenario 2, 500kW	183%	83%	9%	4%
Scenario2, 625kW	203%	103%	10%	5%
Scenario 2, 750kW	209%	109%	10%	5%
Scenario 3, 500kW	154%	54%	8%	3%
Scenario 3, 750kW	186%	86%	9%	4%

These figures suggest that the most favourable rates of return are projected for Scenario 1, 1MW, followed by Scenario 2, 750kW.

Table 21 below shows simple payback periods for biomass CHP/DHN, for the secondary biomass boiler and for a combination of the two. The payback period for the biomass boiler alone is included for the purpose of illustrating its contribution to the whole.

$$\text{Payback} = \frac{Capital\ Cost}{Annual\ Income}$$

Table 21 Simple payback periods calculated for 7 demand/load profiles

Demand /load profile	Size of biomass boiler required to meet peak load (kW_{th})	Simple payback period (years) CHP plant and DHN only	Simple payback period (years) biomass boiler only	Simple payback period (years) CHP/DHN + biomass boiler
Scenario 1, 750kW_e	3500	7.84	79.01	9.77
Scenario 1 1MW_e	3000	6.64	67.72	7.89*
Scenario 2, 500kW_e	3500	11.15	10.40	10.94
Scenario2, 625kW_e	3000	9.62	10.89	9.87*
Scenario 2, 750kW_e	3000	8.60	16.84	9.55*
Scenario 3, 500kW_e	2000	11.90	21.86	12.97
Scenario 3, 750kW_e	1750	9.34	115.18	10.72*

For a project with an expected lifetime of 20 years the most attractive options in terms of simple payback are shown to be:

Scenario 1, 1MW_e; followed by Scenario 1, 750kW_e; Scenario 2, 750kW_e; Scenario 2, 625kW_e; and Scenario 3, 750kW_e.

The four demand/load profiles chosen[46] for further appraisal are highlighted* in Table 21.

The wide variations in payback periods for the heat only boiler from 10+ to 115+ years, are explained by differences in periods of demand for its output as illustrated in Figure 35, showing that for Scenario3, 750kW_e, the only demand on the boiler is during December and January, while for Scenario 2, 625kW_e, demand is spread more evenly over 8 months. Again, while these monthly figures mask daily peak loads, they are useful indicators as to the overall demands made on the secondary plant. The purchase of a boiler only operational for two months p.a. is generally less desirable than purchasing one operating for longer.

[46] Only the most attractive profile for Scenario 1 is chosen for further analysis since this is the optimised scenario, and is included for reference purposes.

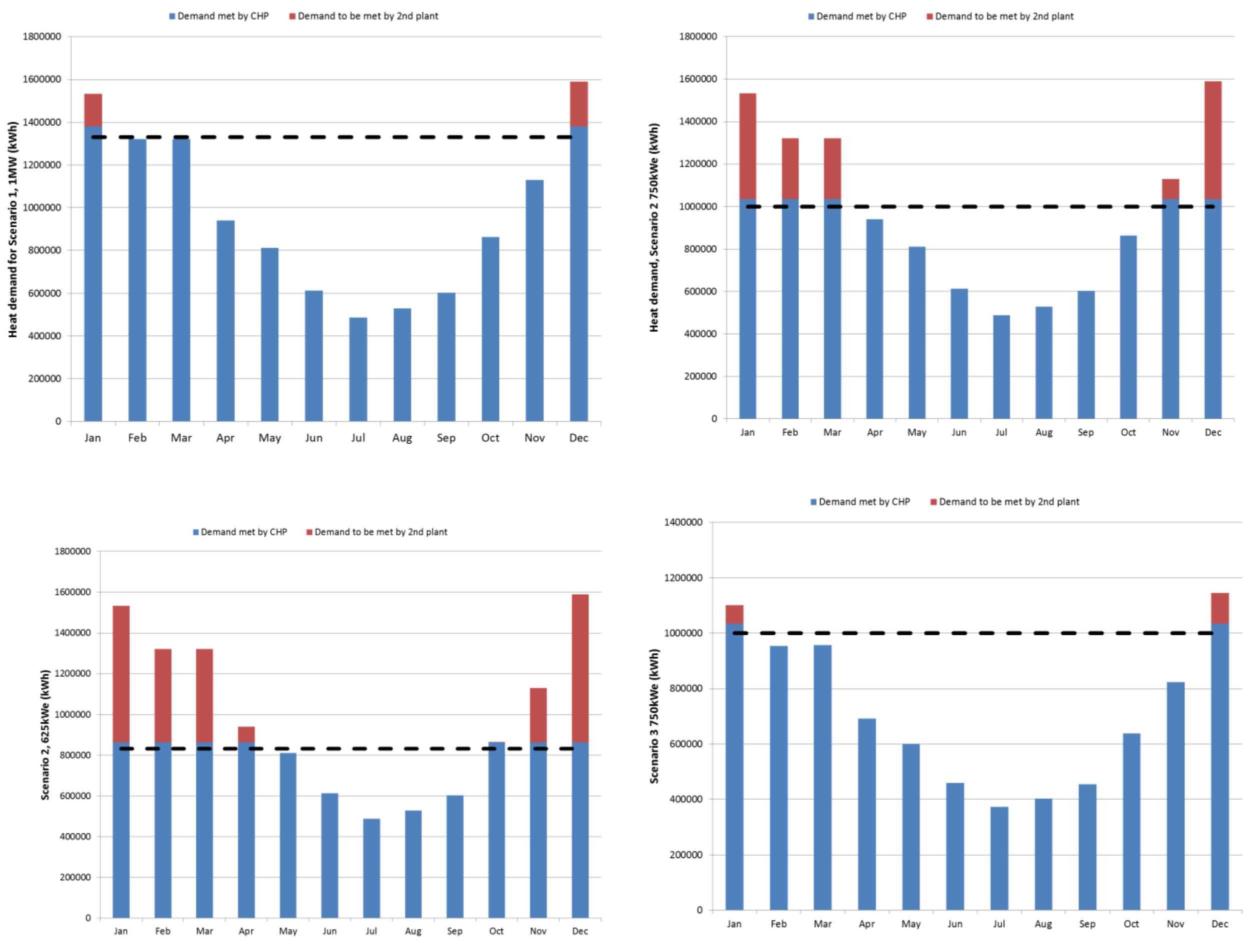

Figure 35a, b, c &d Contribution of the peak demand boiler to overall energy demand for four scenarios

Figure 35 illustrates the constant heat output of the CHP plant as a black dashed line, plus the additional 3.35% heat required for drying the wood. The empty space beneath this line indicates the amount of heat dumped each month, lowest for Scenario 2 and highest for Scenarios 1 and 3.

Capital costs, running costs and annual income associated with these four profiles are presented in Table 22 - Table 24.

Table 22 Capital costs

	Biomass CHP Plant size (kW_e)	Biomass CHP plant	Peak Biomass Boiler	DH Pipes (Aluflex)	Pipelaying /Civils	Buildings /Equipment	Hydraulic Interface Units	Grid Connection	Total Capital Outlay
Scenario 1, 1MWe	1000	€4,300,000	€2,016,000	€3,686,500	€626,705	€150,000	€541,320	€137,572	€11,458,097
Scenario2, 625kWe	625	€2,687,500	€2,016,000	€3,359,980	€571,197	€150,000	€444,600	€137,572	€9,366,849
Scenario 2, 750kW	750	€3,225,000	€2,016,000	€3,359,980	€571,197	€150,000	€444,600	€137,572	€9,904,349
Scenario 3, 750kW	750	€3,225,000	€1,176,000	€2,870,200	€487,934	€150,000	€297,960	€137,572	€8,344,666

Table 23 Annual Running Costs

	Operation & Maintenance	Wood Fuel (transport inc.)	Total
Scenario 1, 1MWe	€430,000	€1,062,236	€1,492,236
Scenario2, 625kWe	€268,750	€977,412	€1,246,162
Scenario 2, 750kW	€322,500	€1,115,287	€1,437,787
Scenario 3, 750kW	€322,500	€1,054,919	€1,377,419

Table 24 Annual Income

	From electricity generated	From Heat Supplied	Total Annual Income
Scenario 1, 1MWe	€1,042,440	€2,042,165	€3,084,605
Scenario2, 625kWe	€651,525	€1,412,912	€2,064,437
Scenario 2, 750kW	€781,830	€1,535,407	€2,317,237
Scenario 3, 750kW	€781,830	€1,216,528	€1,998,358

While undiscounted parameters are useful in indicating the scenarios most likely to deliver a return, in practice investors want to know how well their capital investments will perform in relation to other potential investments. For this, the Net Present Value (NPV) is required.

NPV = = $\frac{1}{(1+r)^n}$ where r is the discount rate and n is the number of years, i.e. the project lifetime. The data is presented in Appendix 1.12.

NPV calculations were performed for the four profiles with the shortest payback periods marked * in Table 21 above, and were then plotted to identify the discount rate at which each profile ceases to offer any returns.

Table 25 Net Present Value of four demand/load profiles at different discount rates

Net Present Value, Scenario 2, 750kW	Net Present Value, Scenario3, 750kW	Net Present Value, Scenario 1, 1MW	Net Present Value Scenario 2, 625kW	Cost of Capital
€8,802,529	€5,697,241	€14,755,561	€7,763,299	1%
€3,014,571	€1,352,637	€6,644,985	€2,463,185	5%
-€1,078,784	-€1,719,950	€909,030	-€1,285,157	10%

Table 25 shows NPV values are positive for all four profiles at future discount rates of 1% and 5% while none are viable at a discount rate of 10%. The rate of return on capital investment was then plotted for each of the scenarios as illustrated in Figure 36 below.

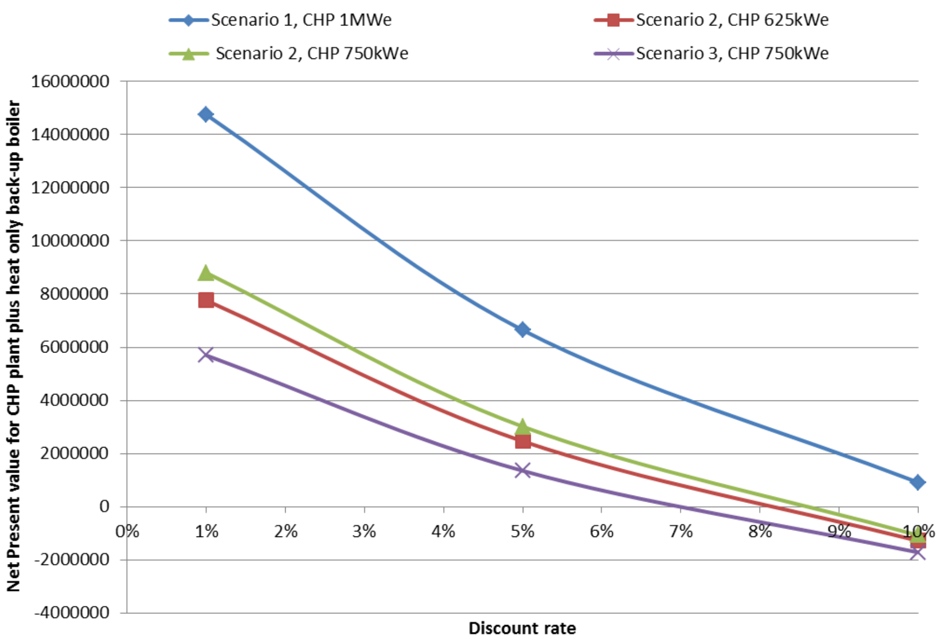

Figure 36 Rate of return on capital investment for four demand/load profiles

Figure 36 illustrates how the rate of return for each demand/load profile falls as the future discount rate rises. The idealised Scenario 1 with $1MW_e$ CHP provides a return on capital investment over a 20-year project-lifespan with a future discount rate over 10%.

Scenario 2 with a 750kW$_e$ CHP plant, Scenario 2, with 625kW$_e$ and Scenario 3, with 750kW$_e$ provide some returns up to a rate of 8.6%, 8.2% and 7% respectively.

While Scenario 1 with 1MW$_e$ is clearly preferred in terms of both simple payback and in resilience to future discount rates, it has already been established that its dependence on 100% residential uptake and no discount is probably unrealistic. In matching current prices it also offers less resilience to price fluctuations, for example if oil prices were to fall (even in the short term), customers may move away. Scenarios 2 and 3 both offer better resilience to this possibility.

Scenario 2, 750kW$_e$ is the next most favourable option, and if the results of the survey could be relied upon, i.e. 82% uptake achievable at 20% discount on current prices, then this demand/load profile could offer both a reasonable payback period as well as some resilience to future discounting up to 8.6%. The detail as to cash flow over a projected lifespan of 20 years is presented in Appendix 1.13.

Carbon Dioxide emissions were also assessed for these four scenarios with emissions values for different fuel types as given by the SEAI (2012a).

Table 26 Potential displacement of CO_2 for each of the four scenarios

			CO_2 displaced for each of the four demand/load profiles (tonnes CO_2)			
Fuel Type	**CO_2 Emissions (g CO_2/kWh)**	**Nominal proportions of each (taken from the survey sample)**	**Sc1, 1MWe**	**Sc2, 750kWe**	**Sc2 655kWe**	**Sc3 750kWe**
Kerosene	257	81%	2618481	2341747	2341747	1671818
Coal	340.6	7%	299898	268203	268203	191476
Peat	374.4	1%	47094	42117	42117	30068
LPG	229.3	1%	28843	25794	25794	18415
Gasoline	251.9	0%	0	0	0	0
Electricity (2009)	553	10%	695595	622081	622081	444116
GRID electricity (2009)	553	100%	4117638	2573524	3088229	3088229
Totals			**7807549**	**5873466**	**6388171**	**5444121**

It is clear that reduction in CO_2 emissions corresponds to the economic returns associated with each demand/load profile, and is highest for the 1MW$_e$ profile.

7.2.5 Assumptions

The following assumptions were made for the calculations involved in the investment appraisal:

- All values are exclusive of VAT.
- The exchange rate used throughout the calculations is £1=€1.20.
- The lifetime of all the plant has been set at 20 years as per manufacturers quotes, as has annual output and efficiency.
- Oil prices and wood fuel prices are valid for the project lifetime.
- The maximum thermal load values are valid for the project lifetime of 20 years.
- Building costs are the same for each scenario.
- The electrical output can all be sold to the grid.
- Operation of the CHP plant is continuous at 8,760 hours per year, with electrical output maintained at optimum levels.
- Operation and maintenance costs include waste disposal and the additional costs associated with secondary plant.
- Monthly figures are averaged over 30 days.
- Peak monthly demand can be used as an approximation of peak load for the purposes of determining the operational time for the secondary plant.

Chapter 8. Discussion, Conclusions and Recommendations

8.1 A Discussion of the Findings and Implications for future research.

The choice of location was based on the simple criteria listed in section 3.2.1. It is possible that other areas meeting these same criteria could produce similarly positive outcomes.

Availability of a suitable local biomass supply was established, but the logistics of a supply chain were not. The existence of the Donegal Woodland owners group, however, along with current developments in mobilising the forestry resource, point to a strong likelihood that a reliable local demand for wood-fuel would stimulate the development of a robust supply chain, as has been demonstrated in Barnsley, UK (Gearty et al 2007).

Because of the lack of good quality reliable data on energy use (such as regular billing data or half hourly data) the heat and hot water demands of the study area were calculated using a high proportion of benchmark figures, estimates and assumptions, as referred to throughout. Wherever possible, the results obtained were compared with other published figures to minimise the chances of wild inaccuracies. It is difficult, however, to assess the level of accuracy achieved until the project is operational. Margins of error are always narrower for small-scale than for large-scale projects. A full-scale feasibility study could draw on the expertise of specialists to bring these within measurable and acceptable limits.

Some key limitations/assumptions and suggestions as to how they might be addressed in such a study are discussed below in more detail:

Degree days are an extremely useful tool in creating annual energy use profiles and are especially useful in monitoring and targeting energy use. However, they are based on the assumption that buildings are kept at a uniform and constant temperature, and as such cannot reflect actual patterns of use in individual homes. Real data would therefore be preferred.

The study attempted to account for energy efficiency improvements already carried out but makes no allowances for future improvements. Energy efficiency improvements should always be the first step when considering reduction of carbon emissions and possible impacts of these on future energy demand in the study area should be included in forecasts.

CHP output was assessed as continuous, i.e. for 8,760 hours annually. This would need to be adjusted to account for the chosen manufacturer’s specifications regarding downtime for maintenance.

DHNs often incorporate a buffer tank to store hot water and provide additional backup, and immersion heaters can also be added at little extra cost to provide further emergency back-up. These possibilities could be explored further.

A full Environmental Impact Study (EIS) would be required to examine the impacts especially of particulate emissions and of the waste stream.

The spread sheet methodology used for the calculations does not easily lend itself to assessing the impacts of different variables. For example, use of a linear algorithm would help to clarify the linear optimisation problem presented, i.e. the interdependencies of plant size, numbers of customers and optimal length of the DHN. A more sophisticated mathematical model would need to be constructed to manage this and other combinations of inputs. This could be especially important for modelling patterns of future demand, especially since the study area is only a subsection of the town and there is a chance that it could expand. The neighbouring town of Ballybofey may also be able to benefit. Modular biomass CHP systems are therefore preferable.

A more complete picture of the environmental benefits and emissions reduction associated with the project would be obtained by comparing its performance with the status quo in terms of:

1. Current emissions from individual oil and solid-fuel boilers;
2. Lifecycle assessments;
3. Harvesting/transport costs;

All necessary planning consents were assumed to be in place as was County Council support. Consultation with relevant decision-makers would be required to ascertain this.

The questionnaire survey proved to be a useful tool both in gathering the data for assessing residential energy demand and attitudes and perceptions of DHN within the sample. Despite its limitations, as discussed in section 4.2 and 4.3, the information on factors that might affect decisions to support the project could prove useful in accentuating positives and eliminating negatives when it comes to marketing. For instance, if older people are more likely to be put off by a new system, a need for early, hands-on demonstrations of the interface units, with information packages targeted at the 46+ age group, is indicated.

The household benefits package[47], paid to pensioners and other on low incomes, is only paid for electricity, natural gas or LPG, so currently mitigates against uptake of DH by this group.

The overall positive response to small-scale CHP/DHN within the sample surveyed hints that public attitudes are not the barrier that has been widely promulgated.

A larger survey, with a truly representative sample of the target population is required to confirm this. Involving local media, press, community groups and leaders could help to recruit larger numbers of participants than is possible through cold-calling.

Following job creation, reinvesting profits in the community was seen as the next most persuasive argument to signing up for CHP/DHN. One way to ensure that this takes place is community ownership of the project. Energy4all and ShareEnergy are examples of the type of support available to communities in the UK, providing practical and technical advice to set up RE projects, from negotiating the planning process and raising finance to operation and management (ShareEnergy 2012), while Energy Supply Companies (ESCOs) provide a different option, whereby the supplier is contracted to install, operate and maintain the plant and to supply heat at an agreed cost.

It is clear from the investment appraisal that tying the price of delivered heat to current oil prices, along with 100% take-up is the most attractive option in economic terms and in reducing CO_2 emissions. In a new-build area, this profile might be possible[48] to achieve, and the capital costs could be reduced[49]. For this study area, however, with the information gleaned from the survey sample, the rate of take-up would be too low for this profile to succeed.

Both the Scenario 2 demand/load profiles appear to offer reasonable payback periods and CO_2 reductions, both are higher for the 750kW$_e$ plant. Advantages of the 625kW$_e$ plant are lower levels of heat dumping and lower capital outlay.

Any full-scale feasibility studies might therefore wish to consider these two profiles in more detail, with particular attention to other emissions including GHGs, particulate emissions, waste and transport emissions. It would also be useful to assess the potential of ORC plant in the range 600 – 800kW$_e$ output.

[47] For details see:
http://www.citizensinformation.ie/en/social_welfare/social_welfare_payments/extra_social_welfare_benefits/household_benefits_package.html
[48] Improved energy efficiency of new buildings would, however, need to be accounted for.
[49] In particular, laying DHN along with other primary services becomes less costly.

8.2 Conclusions

This study is a preliminary assessment and as such can conclude only that there is a strong possibility that CHP/DHN can be viable for a small town in rural Ireland. The narrow financial margins for investment in small-scale CHP/DHN mean that a full-scale feasibility study is needed to provide confidence in its viability. In particular, this would incorporate:

- Accurate, operational performance data from biomass CHP plant manufacturers in terms of outputs, efficiencies and lifespan.
- A DHN consultant to configure and cost the optimal system and layout;
- Conduct of a full Environmental Impact Assessment;
- Consultation with a fully representative sample of householders about the proposal and their participation as customers.

Financial incentives could help overcome some barriers to the levels of capital investment required.

In addition, the following key conclusions are drawn:

- Firstly, the idea that small towns with a heat demand of less than $5MW_{th}$ cannot benefit from DH should be re-examined in the light of new developments in DHN technologies, with towns and villages assessed on a case by case basis.

- Secondly, the widely published assertion that a lack of experience and unfamiliarity of the Irish public with DHN is a barrier to its development deserves reassessment.

- Thirdly, key uncertainties exist in forecasting demand due to lack of availability of good, metered data on energy consumption patterns. While these uncertainties can be minimised through careful cross-checking, the availability of more accurate data, particularly in regard to residential use, becomes more important for small scale projects.

- Finally, while manufacturers of small-scale biomass gasification technologies are understandably reluctant to share detailed performance data, this could be a considerable barrier to their uptake and needs to be addressed as a matter of some urgency if small-scale biomass CHP is to fulfil what appears to be its promising potential. Government support for a small number of pilot projects could assist in overcoming this.

8.3 Recommendations

Eight key recommendations are made to ensure future progress for assessing the suitability of biomass CHP and DHN for small towns in rural Ireland:

1. Establishment of a national database to encourage individuals and small business owners to contribute data towards an energy audit of the building stock. This type of public participation has been successfully used for gathering biodiversity data, e.g. the "iSpot" project[50], and could easily be adapted to gathering information about the housing stock and energy use. If properly managed, this could be an invaluable resource for future development of RE, not to mention an important educational resource and tool for schools and universities.
2. Government or County Council ownership of a number of differently sized small-scale biomass CHP pilot projects. This would ensure that performance data could be made more widely available and in the longer term could provide good returns on the initial investment.
3. Given the small range in which small-scale biomass CHP operates, modular systems which can be expanded or reduced as may be required over a 20 year lifespan would be a preferred option. Modelling how this might affect long term outcomes would be useful for planners.
4. Development of a model to simulate energy demand patterns for rural towns in Ireland, with parameters that can adapt to the lack of access to natural gas, the prevalence of secondary heating systems and the variety within the building stock.
5. Continuation and expansion of the cluster analysis project to identify those areas of forestry that can provide quantities of wood-fuel. There is an urgent need to stimulate private forestry to ensure a supply of wood-fuel beyond 2030, possibly through grant aid as in the 1990's. Continued support for the supervision of plantations and education programmes for farmers in forestry to ensure maximum use is made of the existing resource.
6. A comparison with heat-only biomass systems should be conducted. These may be more sustainable options in some areas as the range of fuel types is wider, eg. hedge clippings etc. (Gearty 2007), less heat is needed for drying and technologies are better established and proven.
7. Further research on public acceptability of small scale, community-based RE projects to properly assess current attitudes and opinions.
8. A government review a Renewable Heat Incentive and the benefits that could accrue in terms of meeting RE targets, job creation and inward investment.

[50] See http://www.ispot.org.uk/

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Appendix A

Supporting material presented during the questionnaire survey

1. Written presentation, given to all respondents

I am in the final year of a Masters degree with De Montfort University, Leicester, and for my dissertation I am doing a study to work out whether, in future, new technologies that are being developed could be used to provide heat and power on a small scale in rural towns and villages from wood (biomass). The system I am looking at is combined heat and power from biomass with district heating, a brief description of how this works is given below. A similar type of system is tried and tested and is popular in other parts of Europe, but so far it mainly operates on a large scale in big cities.

The new technologies would make it possible for much smaller scale power plants to be developed and this might mean that it is possible to locate them in small towns and villages.

My study will help to show whether or not this type of system would be viable in a rural town in Ireland. I have chosen Stranorlar because the power plant is usually located near to a facility that needs heat all year round, such as a swimming pool, so using an area where a swimming pool is planned will make it more realistic.

2. A brief description of Biomass Combined Heat and Power with a District Heat Network (read out to all respondents).

This is a renewable energy system, using biomass (wood waste from forestry or specially grown crops such as willow) to produce electricity and heat. The electricity produced can be used locally or sold into the national grid, while the heat can be used to provide year round heat to a facility such as a leisure centre as well as providing central heating and hot water to homes connected to the system via a district heat network.

District heat networks are a tried and tested way of supplying heat and hot water in other European countries, especially in Denmark where over 80 % of homes are heated in this way. The heat produced as a waste product from electricity generation heats water that is pumped around a network of highly insulated underground pipes. Each house has its own connection and meter, with its own controls to regulate the temperature, with a thermostat and timer just like a conventional central heating system. The conventional boiler and the hot water cylinder are replaced by a single unit, measuring roughly 70cmx45cmx30cm. Pictures of this type of unit, how the plant might look, and the layout of a district heat network are presented for your information.

Important information: I am not collecting any information that can identify you directly or indirectly. The data collected will only be used in a report for my dissertation. Once the data has been analysed, it will be used in a report of the research undertaken and no information will be published that identifies people directly or indirectly.

If you do not wish to take part in this survey, thank you for your time and please feel free to recycle the paper.

Otherwise, thank you for taking part, your help is much appreciated.

There are two parts to the questionnaire.

In part 1 you are asked to answer some questions about your domestic heat and hot water use. This will help me to work out the overall heating requirements for an area like this and to work out the best size of combined heat and power plant.

In part 2 you are asked about your attitudes to the energy service as I have described it to you. This will help me to work out how popular an energy service like this might be and what kind of issues might affect its take up. (Contact details of the researcher supplied.)

3. Images shown to respondents along with the questionnaire survey

The basic layout of a DHN (The Energy Saving Trust,2004)

CHP plant in Vauban, Freiburg, Germany, (Wörner n.d)

Hydraulic Interface Units for Houses, The Danfoss Akva Lux VX (Danfoss 2012)

Appendix B

Annotated copy of the Survey Questionnaire

The questionnaire as delivered is typed in black

Results are shown in red - total number of responses (%age of responses in brackets)

Codes for the purpose of analysis are shown in green

Instances of data cleaning are marked in blue.

PART I Your domestic heating and hot water use.

1. Which of these descriptions best fits your home?

1Detached 15(32) 2Semi-detached (incl. end terrace) 20(43) 3Mid-terrace 10(21)

4Flat/apartment 2(4)

2. How is your home laid out?

1On one floor 10(21) 2Over 2 floors 37(79) 3Over 3 floors ☐ 4Over 4+ floors ☐

3. Do you have central heating (ie water filled radiators?)

1Yes 46(98) (go to next question) 2No 1(2) (skip the next question)

4. Which fuel does your central heating run on? NB 1 blank , no central heating (%age of 46)

aGas cylinder 0 bOil 42(91) cCoal 5(11) dTurf 2(4) eElectricity 0

fWood 0 gOther 3(7) - identified as bulk LPG serving the apartment block.

[?Blank 0=chosen] otherwise 1=chosen 0=not chosen

5. Which other heating fuels do you use? (eg. In a range, a stove, an open fire, plug-in electric heaters) Tick all boxes that apply. NB 10 blank (%age of 37)

aGas cylinder 5(14) bOil 6(16) cCoal 28(76) dTurf 8(22) eElectricity 8 (22)

fWood 17 (46) gOther 1(3)

[?Blank 0=chosen] otherwise 1=chosen 0=not chosen

6. How do you heat your tap water? Tick all boxes that apply.

aGas cylinder 0 bOil 33(70) cCoal 13(28) dTurf 3(6) eElectricity 35(74)

fWood 3(6) gOther 1(3)

7. When was your house built?

1Since 2002 10(21) 21992-2001 12(26) 31982-1991 6(13) 41979 -1981 1(2)

51972 -1978 6(13) 6Before 1972 11 (23) 12 (24) 7Don't know 1(2) 0 Cleaned - added to "Before 1972" – to bring the age of this house in line with the other houses in this block.

8. Have you had any major energy efficiency improvements carried out? (eg. Increased insulation, double glazing, a new boiler, solar panels fitted)

1No 17(36) 2Yes 30(64)

8a attic insulation19(40) 8b cavity wall insulation 11(23) 8cnew boiler +tank 10(21) 8d other 14(30) (for all other improvements and for a,b, and c if carried out more than 10 years ago)

9. What best describes your seasonal pattern of central heating?

1All year round 17(36) 2September – May only 16(34) 3October – April only 12(26)

4Other 2(4) please describe_______________________________________

10. What best describes your weekly pattern of central heating use?

1Mornings and evenings on weekdays plus daytime at the weekend 8(13)

2Mornings and evenings only 13(28) 3Evenings only 16(34)

4All day every day 9(19)

5Other (please describe briefly) 0________________________________

11. What best describes your weekly pattern of hot water use?

1Mornings and evenings on weekdays plus daytime at the weekend 7(15)

2Mornings and evenings only 14(30) 3Evenings only 14(30)

4All day every day 8(17)

5Other (please describe briefly) 4(9)________________________________

12. Which of the phrases below best describes your role in heating your home? Tick all that apply:

aI am a bill-payer 42(89) bI control the heating and hot water system 40(85)

cI use the heating and hot water system 44 (94) where 1=chosen 0=not chosen

13. How many people are in your household?

1	2	3	4	5	6	7	8	9	10+
8	14	13	7	4	1				
(17)	(30)	(28)	(15)	(9)	(2)				
1	2	3	4	5	6	7	8	9	10+

PART 2 Your thoughts about CHP and district heating as it has been described to you.

Please could you let me know what you think about the idea of a district heating scheme fuelled by woodchip as it has been described to you by answering the remaining questions?

1. Have you heard about this type of energy service before?

Tick one box 1Yes 12(26) 2No 35(74)

2. What is/was your first reaction to the idea of biomass CHP and district heating?

Tick one box

1It's a good idea 23(49) 2I'd like to know more about it 18(38) 3I don't like the sound of it 5(11)

CLEANED (+1 who recorded an answer of "not bothered" – moved to "I don't like the sound of it")

3. How interested would you be in connecting up to such a scheme if it became available in your area?

1Very interested 11(23) 2Quite interested 21(45) 3Not interested 4(9) 4Undecided 11(23)

4. Would any of the following issues concern you? Tick all that apply.

1Connection cost 41(87)

2Disruption to local roads during construction 10(21)

3Using woodchip as a fuel 8(17)

4Using a different system than the one you are used to 15(32)

5Other issues (please describe) ____

5. Would any of the following issues improve the chance of you joining the scheme?

a. Improving the energy rating of your home

1Yes 25(53) 2No 11(23) 3Don't know 11(23)

b. Proceeds from electricity sales are reinvested in the local community e.g. providing grants for better insulation and home energy conservation.

1Yes 37(79) 2No 3(6) 3Don't know 6(13)

c. The creation of local jobs to operate the plant.

1Yes 42(89) 2No 2(4) 3Don't know 3(6)

d. Creation of local jobs in forestry/agriculture to supply the plant.

1Yes 43(91) 2No1(2) 3Don't know 2(4)

e. Use of the plant as an educational facility for local schools to learn about renewable energy.

1Yes 35(74) 2No 5(11) 3Don't know 7(15)

f. The availability of extra space in and around your home due to removal of oil tank, boiler and hot water cylinder

1Yes 24(51) 2No 20(43) 3Don't know 1(2)

6. How might costs affect your decision to switch to a district heat network?

Please complete the sentence below with the first phrase in the list that most closely reflects your opinion.

I would switch to this supply ….

1a. even if my fuel bills could rise 1(2)

2b. if my fuel bills stayed the same 7(15)

3c. if my fuel bills were guaranteed to be at least 10% lower 18(38)

4d. if my fuel bills were guaranteed to be at least 20% lower 13(28)

5e. if my fuel bills were guaranteed to be more than 33% lower 8(17)

6f. never, I would prefer to stick with the system I have at the moment 0

7. How would you rate your general attitude to renewable energy?

Please mark your position on the arrow below with a cross.

1Strongly in favour	2In favour	3Unsure	4Against	5Strongly against
12(26)	24(51)	10(21)	1(2)	

8. Please finish by providing some information about your status and home ownership by ticking the relevant boxes below.

a. 1Female 32(68) 2Male 15(32)

b. 1Under 16 0 216-30 9(19) 330-45 13(28) 445 - 60 12(26) 560-75 10(21) 675+ 3(6)

c. 1Renting - Council tenant 16(34) 2Renting - Private tenant 8(17) 3Home owner 23(49)

If you wish to make any further comments please do so in the space provided below.

Comments are appended in Appendix 1.1

Thank you very much for taking the time to fill in this questionnaire.

Appendix C

The cost of wood chip is calculated as €0.0371/kWh with an additional cost for transportation of €0.00198/kWh, a total of 3.908c/kWh delivered energy, based on the following:

Assume logs purchased at 30% moisture content and chipped and dried on site to 15% moisture content (see BEL fuel spec). Conifer wood will dry to 30% mean moisture content using ambient air drying alone (top-covered) over a 12 month period (Kent, Kofman and Coates, 2011) Prices are based on Sitka Spruce as the predominant crop in the area.

The following calculations are based on Kofman (2010):

Bulk density of Sitka Spruce at 30% moisture content = 206kg/m^3

Cost per tonne = €27m^{-3} x 1000kg/206kgm^{-3} = €131.07

Average Net Calorific Value (NCV) of conifers = 19.2 GJ/tonne.

NCV = 19.2 – (0.2164 x MC) where MC is the %age moisture content.

So in this case, NCV = 19.2 – (0.2164 x30) = 12.708 GJ/tonne

1GJ=0.278MWh

1 MWh is 1/0.278GJ = 3.597GJ

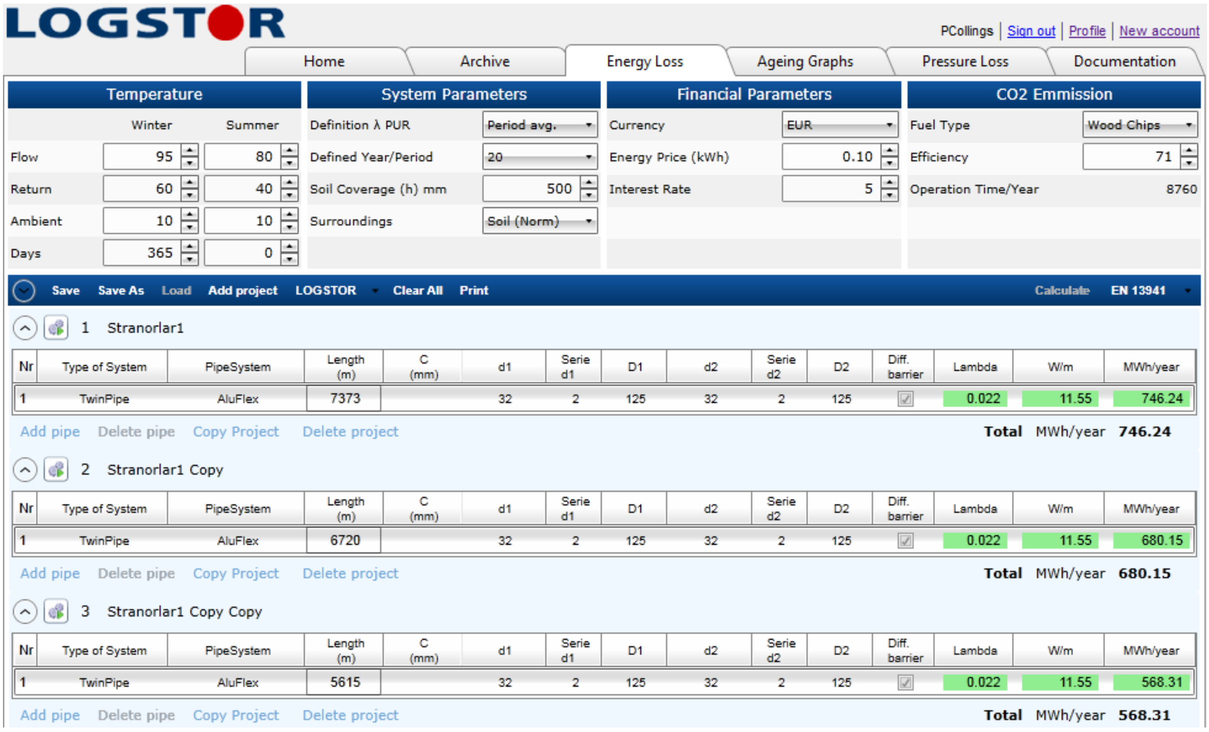
Energy delivered = NCV/3.597 = 3.533MWh/tonne (3533kWh/tonne)

Cost per GJ= cost per tonne/12.708 GJ = €131.07/12.708GJ = €10.31/GJ

Cost per MWh (delivered) where1GJ=0.278MWh is €10.31/0.278 = €37.09/MWh or €0.0371/kWh

Transport costs based on €7/tonne for 3533kWh/tonne delivered energy = €0.00198/kWh

Appendix D



LOGSTOR

PCollings | Sign out | Profile | New account

Home | Archive | Energy Loss | Ageing Graphs | Pressure Loss | Documentation

Temperature	Winter	Summer
Flow	95	80
Return	60	40
Ambient	10	10
Days	365	0

System Parameters	
Definition λ PUR	Period avg.
Defined Year/Period	20
Soil Coverage (h) mm	500
Surroundings	Soil (Norm)

Financial Parameters	
Currency	EUR
Energy Price (kWh)	0.10
Interest Rate	5

CO2 Emmission	
Fuel Type	Wood Chips
Efficiency	71
Operation Time/Year	8760

Save Save As Load Add project LOGSTOR Clear All Print Calculate EN 13941

1 Stranorlar1

Nr	Type of System	PipeSystem	Length (m)	C (mm)	d1	Serie d1	D1	d2	Serie d2	D2	Diff. barrier	Lambda	W/m	MWh/year
1	TwinPipe	AluFlex	7373		32	2	125	32	2	125	✓	0.022	11.55	746.24

Add pipe Delete pipe Copy Project Delete project **Total** MWh/year **746.24**

2 Stranorlar1 Copy

Nr	Type of System	PipeSystem	Length (m)	C (mm)	d1	Serie d1	D1	d2	Serie d2	D2	Diff. barrier	Lambda	W/m	MWh/year
1	TwinPipe	AluFlex	6720		32	2	125	32	2	125	✓	0.022	11.55	680.15

Add pipe Delete pipe Copy Project Delete project **Total** MWh/year **680.15**

3 Stranorlar1 Copy Copy

Nr	Type of System	PipeSystem	Length (m)	C (mm)	d1	Serie d1	D1	d2	Serie d2	D2	Diff. barrier	Lambda	W/m	MWh/year
1	TwinPipe	AluFlex	5615		32	2	125	32	2	125	✓	0.022	11.55	568.31

Add pipe Delete pipe Copy Project Delete project **Total** MWh/year **568.31**

Source: Logstor (2012)

Word Count:17981/21733